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Volume V 1952

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University of Arkansas, Fayetteville

April 27-28, 1951

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SATURDAY MORNING, APRIL 28

8:45 Second Business Meeting. Treasurer's Report
Report of Standing Committees
Report of Special Committees
Election of Officers
Appointment of Committees
Location of next year's meeting
New business

9:30 Symposium. Resources of Arkansas.

Agriculture, Dean L. S. Ellis, University of Arkansas.

Industrial, W. W. Shepherd, Arkansas Power & Light Company.

Mineral Resources, J. N. Payne, University of Arkansas.

Education, C. F. Byrns, Southwestern American.

Research, F. Soday, Lion Oil Company.

Social Resources, H. S. Ashmore, Arkansas Gazette.

12:00 Arkansas Academy of Science, 35th Annual Meeting adjourned.

SATURDAY NOON, APRIL 28.

12:15 Informal luncheon

SATURDAY AFTERNOON, APRIL 28

1:30 Field trip to "the Narrows" of White River east of Springdale. Arranged by D. M. Moore, Professor of Botany, University of Arkansas.

1:30 Participation in Agri Day.

Officers of the Academy:

President:	R. H. Austin
Vice-President:	H. B. Foxhall
Secretary:	W. W. Grigorieff
Treasurer:	T. L. Smith
Editor:	Dwight M. Moore

Program Committee:

Z. V. Harvalik, Term 1950-1951

W. J. Smothers, Term 1951-1952

A. M. Wilson, Publicity

L. B. Ham, Local Arrangements

ARKANSAS ACADEMY OF SCIENCE

SECRETARY'S REPORT
on the 35th Annual Meeting
University of Arkansas, Fayetteville
April 27 and 28, 1951

President R. H. Austin formally opened the 35th meeting of the Academy at 10:30 A.M. on Friday, April 27, in the Chemistry Auditorium. The Honorable Powell Rhea, Mayor of Fayetteville, warmly welcomed the participants in a short address emphasizing the significance of scientific contributions to our daily life on the national, state, and local levels.

The first business meeting of the Academy was called to order by President R. H. Austin at 10:40 A.M. The minutes of the 1950 meeting as they appeared in Volume IV of the Proceedings were approved.

The following committees were appointed:

Nominating: C. V. Robinette, P. G. Horton, T. L. Smith

Resolutions: J. R. Mundie, W. C. Munn, Mrs. Jean Williams

Auditing: D. M. Seward, O. J. Hall, O. C. Estes, L. E. Porter

Meeting Place, 1952: W. K. Noyce, Howard Baker, I. A. Wills

Research: R. R. Edwards, Delbert Swartz, M. E. Thompson

Professor Z. V. Harvalik, chairman of the Policy Committee, presented recommendations of his committee, which were acted upon as follows:

(a) It was moved, seconded, and passed that the standards of quality of papers and articles should be further increased.
(b) It was moved, seconded, and passed that the Proceedings should be further improved and continued as an annual publication.
(c) It was moved, seconded, and unanimously approved that the annual fees be increased to $3.00.
(d) It was resolved that the Academy sponsor a Junior Academy.

Professor W. H. Bennett gave an address on "The Mascope--A New Analytical Instrument" to the general meeting of the Academy.

The morning session was adjourned at 12:10 P.M.

Following a luncheon served in the Student Union, President Lewis Webster Jones of the University of Arkansas gave a warmly-received presentation entitled "Science in the Service of the People."

The sectional meetings of the Academy took place at 2:00 P.M. A total of 74 papers was presented in ten different sections. The attendance at all sessions was approximately 250.

Members of the Academy reconvened for dinner at the Washington Hotel. The dinner was followed by an address by Professor Irwin Edman, of the Department of Philosophy of Columbia University, at the Art Center Auditorium at 8:00 P.M. Professor Edman spoke on "Art as Education in Freedom." The talk brought to the audience significant thoughts on the interrelationship of the arts and sciences and was the subject of continued discussions.

The second business meeting of the Academy was called to order on April 28 at 8:45 A.M.

(a) D. M. Seward presented the report of the Auditing Committee, and it was accepted.
(b) It was moved, seconded, and passed to approve with thanks the report of the Treasurer, showing a balance of $210.00.
(c) It was moved, seconded, and approved that the National Science Foundation Committee be dismissed and that the Research Committee deal with matters pertaining to the Foundation.
(d) Approval of J. R. Mundie's report of the Resolutions Committee was moved, seconded, and passed.
(e) The report of the Policy Committee, presented by Z. V. Harvalik, was accepted as a guide for future action.

(f) Following the presentation by T. V. Smith of candidates for membership in the Academy they were duly elected.

(g) C. V. Robinette presented the Nominating Committee's recommendations, and the following were elected for 1952:

President: E. A. Spessard
Vice-President: Delbert Swartz
Secretary: W. W. Grigorieff
Treasurer: T. V. Smith
Editorial Board: C. E. Hoffman, Chairman
D. M. Moore
W. K. Noyce
Leta M. Adler
Z. V. Harvalik

(h) It was moved, seconded, and agreed, on the recommendation of W. K. Noyce, that the 36th meeting be held in Jonesboro on April 25 and 26, 1952.

The new President, E. A. Spessard, adjourned the business meeting at 9:35 A.M.

A symposium on "The Resources of Arkansas" was presented by six speakers representing important phases of Arkansas activities. (M. D. Barnes presented the talk, prepared by F. Soday, who was unable to attend.)

The 35th meeting of the Academy was adjourned by President Spessard at 12:15 P.M.

Many Academy members participated in field trips and the Annual Agri Day festivities in the afternoon.

The 35th annual meeting was characterized by a further growth of the Academy activities, particularly in the direction of a Junior Academy. The membership, numbering 141 at the time of the meeting, is continuing to give enthusiastic support to the expanding program of the Academy.

W. W. Grigorieff, Secretary

ARKANSAS ACADEMY OF SCIENCE

ABSTRACTS OF PAPERS PRESENTED AT THE THIRTY-FIFTH ANNUAL MEETING

University of Arkansas, Fayetteville

April 27-28, 1951

BIOLOGY SECTION

Chairman: E. A. Spessard, Hendrix College

B-1-1

Virus Diseases in Arkansas Strawberries. J. P. Fulton, University of Arkansas.

In studies using the Marshall variety of strawberries as an indicator plant, Blakemore strawberry clones from various parts of Arkansas were indexed for the presence of virus. Nineteen clones gave a positive virus reaction and three were negative. Field studies with ten of the indexed Blakemore clones indicated that the presence of virus adversely affected runner production and general vigor of the plants. In an attempt to locate a better indicator plant grafts were made using seedlings of selfed Marshall plants, seedling of *Fragaria vesca*, seedlings of *F. virginiana*, and seedlings of Baron Solemacher, a runnerless variety of *F. vesca*. Baron Solemacher proved to be the most valuable indexing plant. Transmission was accomplished by grafting a runner of the symptomless carrier to a leaf petiole. Symptoms appeared rapidly and were expressed as severe, mottling, distortion, and stunting. Once initial symptoms appeared there was no tendency toward a recovery or masking of symptoms. Attempts to transmit this virus mechanically or by means of dodder were negative.

B-4-4

New Additions to the Flora of Arkansas. Lloyd G. K. Carr, Hendrix College.

The author has been much impressed by the nature of the floristic types of northern Arkansas, primarily in the Boston Mountain region where the author's investigations have chiefly centered.

Several new additions to the flora of Arkansas will be presented from this region. Conspicuous here are *Dicentra Cucullaria* (L.) Bernh., forma *purpuritincta* E. H. Eames; *Comandra Richardsiana* Fern.; *Lithospermum croceum* Fern. Some physiographic features will be discussed as a background for the floristic types present, that is in the light of the geological history of the province concerned.

B-5-5

Nuclear Phenomena and the Formation of Motor Organelles During Mitotic Division in the Euglenoid Flagellates. James H. Fribourgh, Little Rock Jr. College.

Species of *Euglena* observed in this study were *E. viridis, E. gracilis, E. pisciformis* and *E. agilis*.

Mitosis in these species of Euglena is accomplished in a manner quite similar to that described for higher plants and animals. Definite chromosomes are formed, divide longitudinnally and are distributed equally to the daughter cells. The chromosomes are formed from the chromatin of the outer nucleus and not from the endosome. The endosome appears to be the ultimate source of all the kinetic elements of the cell.

Actual division of the nucleus is preceded by its migration anteriorly until it comes into close contact with the lower border of the resorvoir in the anterior end of the organism.

The flagellum, basal body and blepharoplast of the parent disappear during division, a new motor apparatus arising in each daughter animal.

During the prophase, the kinetic complex buds off the endosome and migrates to the periphery of the nucleus where it subsequently divides. The products of this division migrate to opposite sides of the anterior border of the nucleus. The bud, or kinetic complex, gives rise to the blepharoplast which produces a basal body.

After formation of the blepharoplast, the residue of the kinetic complex is retained in the nuclear membrane until division is completed. The residue then passes into the cytoplasm where it remains until the next successive mitosis when it disintegrates.

A rhizoplast passes from the kinetic complex to the blepharoplast. In each daughter animal, an intra nuclear rhizoplast connects the residual mass with the endosome. During reorganization, these connections likewise disintegrate.

B-6-6

Poisonous Plants in Arkansas. Dwight M. Moore, University of Arkansas

An account of the more important plants of Arkansas which are poisonous to man or livestock. Kodachromes are used to show various aspects of plants long known to be poisonous, and several either new to the state or only recently found to be poisonous.

CHEMISTRY SECTION

Chairman: T. E. McEver, Arkansas Polytechnic College

C-1-11

A Preliminary Report of the Spectrophotometric Determination of Magnesium with Eriochome Black T. George M. Wyatt and Aubrey E. Harvey, University of Arkansas.

A method is being investigated for the direct spectrophotometic determination of magnesium using Eriochome Black T as a complexing agent. The red complex formed is very stable and interference from other ions is negligible. The intense blue color of the reagent necessitates the use of dilute solution or of very short optical paths. The reagent is sensitive enough to detect magnesium in ordinary distilled water. For this reason conductivity water was used for all standard solutions.

C-2-12

Some Raw Materials that Might Support Arkansas Industries. M. E. Barker, University of Arkansas.

We have many unused natural resources in this state which might support major industries to the economic advantage of the people of this state. Three years ago the Department of Chemical Engineering, University of Arkansas, started a modest research and development program to work out the technical details of using some of these raw materials.

Last year we reported a preliminary investigation of sericea lespedeza for paper making. We have extended this investigation into other fields and will report three (3) phases of this investigation today.

In addition, promising results are being obtained in the production of cement, building blocks, light-weight aggregate, distillation of oil shale, and the manufacture of high quality activated charcoal. We hope to report more results to you next year.

C-4-14

Wallboard. How it is made from Arkansas raw materials. Samuel Griffith, University of Arkansas.

Lesedeza sericea and scrub oak, at the present time, are not being used for any industrial purpose but are satisfactory raw materials of pulp for wallboard. The cost of removing the bark and the comparatively short fibers of scrub oak have prevented it from being used as a source of pulp. However, sericea pulped with its bark and branches has proved to be a very satisfactory source of pulp for wallboard. By using oak bark as a source of tannin and combining the pulping operation with the tannin recovery, scrub oak becomes economically available for wallboard manufacture.

The process for the production of wallboard is much like that of paper in the initial stages. Reagents are added to the furnish, or in the dry mixing process, to improve the desired characteristics of the board such as strength, water-proofness, and insulating value. After the formation of the board, it is subjected to a heat and pressure treatment for a period of time to impart the desired strength and density.

C-5-15

Conversion of Sericea Pulp into Chemical Derivatives. John G. DePagter, University of Arkansas.

Sericea pulp containing 92% or more alpha cellulose is excellent for the production of viscose rayon, cellulose acetate, and methyl or ethyl cellulose.

The preparation of viscose rayon involves reacting the pulp with carbon disulfide and sodium hydroxide under controlled conditions. Viscose rayon from sericea is dark in color with good tensile strength, and is very suitable for cloth.

The cellulose acetate is prepared by reacting the sericea pulp with acetic anhydride and acetic acid, using sulfuric acid as a catalyst.

The cellulose ethers, methyl and ethyl cellulose and others, are formed from the sericea pulp using the Williamson reaction for the preparation of organic ethers. These ethers are used for plastic films and in the preparation of insulating coatings for electric wires.

These are among the most important of the many compounds which can be prepared from sericea pulp. All of these compounds have major market possibilities, both as to quantity and as to dollar volume.

C-6-16

Heat Transfer to Boiling Liquids. Carl M. Gamel, Jr., University of Arkansas.

Although the typical curve of heat flux density plotted against the temperature difference from the heating surface to the bulk of the liquid has been qualitatively explained by Nukiyama and others, little has been made available to offer a quantitative prediction of flux densities. This is particularly true in the film boiling and high nucleate boiling range. The flux density at a given temperature difference should increase with increasing turbulence. However, this increase may be limited by cavitation. It has also been established that the flux density is a function of pressure, temperature, viscosity, surface tension, thermal conductivity, and the geometry and nature of the heating surface. Almost without exception the data obtained on any one variable have been quite limited.

Due to the high amounts of energy required at the higher flux densities, most of the data have been obtained in the laboratory using fine, electrically heated wires. This presents several serious difficulties due to longitudinal and radial gradients, and the fluctuations of the electrical energy input.

The accurate prediction of heat flux densities to boiling liquids and the adequate control of them would be a great step in the field of heat transfer. There is a great need for the information in rocket development, and the development of small, light weight steam generating equipment.

C-7-17

Coseparation of Sulfate Ion with Barium Chromate. Morton Dworshak, College of the Ozarks.

The problem was to determine the fraction of sulfate ion at micro concentrations which would be coseparated with a macroscopic amount of barium chromate precipitated from an aqueous solution containing both the chromate and the sulfate ions, and also to attempt to determine the nature of the coseparation process. The sulfate ion was present in the coseparation solutions in such concentrations (of the order of 10^{-15} moles/1.) that after the addition of the barium ion the solubility product of barium sulfate was not exceeded.

Radiosulfur was used as a tracer in making the determinations. A scaler, Geiger-Mueller tube, lead shield micropipettes, and other radiolab accessories were employed in counting and measuring the tracer concentrations.

Results were gratifying although not unexpected in the light of previous knowledge of laws of chemical separation and coprecipitation.

C-8-18

Investigation of the Dropping Mercury Electrode for Alkali Determination. W. J. Smothers, University of Arkansas.

The fundamentals of the dropping mercury electrode are discussed. Typical curves are presented with methods of measurement of critical values discussed. The use of this instrument for qualitative and quantitative work is mentioned. Curves are given for alkali determination in which a "control" ion is used to improve accuracy. Mixtures of sodium and potassium in varying proportions were run and results given. In the range of concentrations studied the polarographic method served as a method of determination of sodium and potassium ions when mixed in a preferred electrolyte.

C-10-20

A Laboratory Experiment in the Determination of Formal Oxidation Potentials. Delmer L. Manning and Aubrey E. Harvey, University of Arkansas.

The procedure used by Walden, Hammett and Chapman [J. Am. Chem. Soc., 55 2649 (1933)] for the determination of formal oxidation potentials by a potentiometric titration has been revised to make it adaptable as a one period laboratory experiment in physical chemistry or instrumentation. Experiments were run using several electrode combinations. Excellent agreement with the accepted values was obtained for the potential of the ferric-ferrous couple, ferric-ferrous orthophenanthroline complex and the cerric-cerrous couple. This points out the fact that many research procedures may be simplified into satisfactory laboratory experiments.

GEOLOGY SECTION

Chairman: R. C. Baker, U. S. G. S., Little Rock

G-1-25

Fault System of the Curry Field Ouachita County, Arkansas, J. O. Staggs, U. S. G. S.

The Curry Field is located near the southwest corner of Ouachita County, three and one half miles northwest of Stephens, Arkansas and one mile east of the common corner of Nevada and Columbia Counties in Sections 5 and 6, Township 15 South, Range 19 West.

Accumulation of oil is controlled by a complex fault system, which is dominated by one major normal fault with approximately 1200 feet displacement. Associated with the major fault are several minor faults with displacement ranging from 10 feet to 175 feet.

The field is unusual among normal faulted fields in that it has two-generation faulting. Two-generation faulting is defined simply as faulting of two different ages following along established fault planes.

In developing the field eighteen wells were drilled with only two unfaulted. Eleven of these wells produced, but by January 1, 1951, three had been abandoned.

G-2-26

Rapid Density Determination of Powdered Minerals and Ceramic Materials. Theodore Dziemianowicz, University of Arkansas.

Since so many equations used in ceramic calculations contain a "True Density" term, need has arisen for a rapid and reasonably accurate method of determining the "True Density" of ceramic raw materials.

Due to contamination by associated minerals, densities of ceramic materials vary considerably, even within each separate classification. For each ceramic material under test therefore, it has become necessary to run separate "True Density" determinations rather than to accept some standard text value for the classification into which the test material might fall.

This is a rather tedious procedure, if carried out by the standard accepted Picnometer Method, where four separate weighings, accurate to the fourth decimal point are necessary. A simple, rapid, and yet reasonably accurate method, making use of only a volumetric flask and calibrated burette, has been developed. Reasonably accurate results have been obtained up to the second decimal point. This method therefore, falls within the limits of required accuracy, since almost all ceramic calculations demand accuracy only up to the second decimal place.

The rapid method as well as the standard method procedures are described. A tabulated comparison between the two methods as well as standard text values with percent deviation are presented.

G-3-27

Detailed Stratigraphy at Norfork Dam, Baxter County, Arkansas. Raymond E. Whitla, Geologist, Little Rock District, Corps of Engineers.

Norfork Dam was constructed across North Fork River in Baxter County, Arkansas, 4.8 miles upstream from the junction of that river and White River. The rock layers that crop out in that area belong to the Everton, the Powell, and the Cotter formations, all of which are of lower Ordovician age.

Approximately 140+ feet of beds at Norfork Dam represent the lower part of the Everton formation. The upper 30+ feet of these are composed of sandstone and sandy clay and belong to the Calico Rock sandstone member of the Everton formation. That part of the Everton formation beneath the Calico Rock sandstone is composed of dolomite or dolomitic limestone, a few thin beds of quartzite and quartzitic sandstone, and a dolomitic shale bed.

The Powell formation at Norfork Dam is 170 feet thick and is composed of fine-grained dolomite beds; shaly, laminated dolomite beds; shale beds; and one chert bed. The chert bed is the result of nearly complete replacement of a crystalline dolomite bed by chert. Shallow water environment at the time of deposition of many of the beds is evidenced by the occurrence of current marks, ripple marks, and dessication cracks. Cryptozoan structures were observed in two beds.

Only the upper part of the Cotter formation crops out in the vicinity of Norfork Dam and cores were drilled only to a maximum stratigraphic depth of 160 feet below the top of the Cotter. These beds consist, for the most part, of fine-grained dolomite. A few laminated dolomite beds and two shale beds, however, do occur in that part of the Cotter section.

A detailed stratigraphic section showing the thicknesses, the characteristics, and the sequence of the individual rock layers composing these formations at Norfork Dam is presented.

G-6-30

Areal Distribution of Surface Radioactivity in the Potash Sulphur Springs Complex, Garland County, Arkansas. Robert H. Arndt, P. E. Damon, and R. B. Stroud, University of Arkansas.

Reconnaissance with a Geiger counter showed that the contact zone of the three-quarter-mile-wide nepheline syenite complex at Potash Sulphur Springs, Garland County, Arkansas contains some unusually radioactive areas. A 100-foot square grid pattern was laid out in a zone about 600 feet wide, around the perimeter of the complex, and straddling the contact of syenite and sedimentary rocks. Three to five minute counts of the radioactivity were made at each grid point with a Geiger counter. Geology was mapped between points. Local background counts were reduced to rock background count and expressed as the ratio, rock background count to daily standard base background count. Radioactivity over about 14 acres on the southern contact and one acre on the northeastern contact is three times base background or higher.

Bedrock in the high radioactivity zones is strongly altered, friable, light-colored syenite. The average radioactivity of other individual syenite types exclusive of lamprophyre ranges from 1.8 to 2.0 times base background, and the overall average is 1.86. The average radioactivity of sandstone and quartzite, the predominant country rock, is one times base background exclusive of the southern border where the activity is 2.3 times base background. Black shale at the southern border has radioactivity of two times base background although in areas away from the syenite complex the same shale is 1.5 times as active as base background. It is believed the highly altered state of the light-colored syenite, and the unusually high radioactivity of syenite, sandstone, and shale at the southern and northeastern contacts are in part the result of hydrothermal alteration and the introduction of radioactive material by hydrothermal processes. Samples of radioactive rock from the northeastern contact zone contain as much as 0.5% U_3O_8 by chemical analysis.

G-8-32

Geologic Guide to Prospecting for Radioactive Materials in Arkansas. Robert H. Arndt, University of Arkansas.

Recent discoveries of thorium at Magnet Cove, Hot Spring County, and uranium at Potash Sulphur Springs, Garland County, in nepheline syenite and related pegmatite and vein deposits may lead to extensive prospecting in Arkansas. Many of the principal geological environments in which uranium and thorium occur in other areas have counterparts in Arkansas. Uranium and thorium occur with the accessory minerals in igneous rocks and in related pegmatites. The nepheline syenite of Granite Mountain, south of Little Rock, Pulaski County, and near Bauxite, Saline County, and numerous minor bodies of igneous rock in Hot Spring, Garland, and Perry counties are related to the uraniferous syenite complex at Potash Sulphur Springs. The water-laid tuffs of syenitic character which occur in the Woodbine and Tokio formations, Pike, Howard, and Sevier counties may be radioactive. Numerous quartz veins in the Ouachita Mountains and vein deposits of cinnabar and stibnite in Pike and Sevier counties indicate extensive hydrothermal mineralization and merit investigation. Sedimentary phosphates similar to uraniferous phosphates of other localities within the United States occur near Batesville, Independence County. Thick black shales of Ordovician and Carboniferous age underlie extensive areas in central, central western, and northwestern Arkansas. Ordovician shale in the Ouachita Mountains is appreciably radioactive. Chattanooga shale crops out in northwestern Arkansas. Placer deposits bearing monazite have been reported in the Arkansas River valley near Morrilton. No counterpart of the Colorado carnotite deposits is known in Arkansas.

Manganese oxides deposited by the hot waters of Hot Springs National Park are radioactive. Other hot springs occur at Caddo Gap, Montgomery County, in southwestern Montgomery County, and in northern Pike County. Manganese deposits in the Arkansas novaculite at Caddo Gap are radioactive. Springs and manganese deposits are worthy of investigation. Petroleum, brine, and cuttings from oil wells should be inspected for radioactivity.

HISTORY AND POLITICAL SCIENCES SECTION

Chairman: R. Hostetter, University of Arkansas

HP-2-35

Separation of Powers Revisited Its Impact on Adminstrative Law.* Reginald Parker, University of Arkansas.

The idea of adminstrative law as a legal discipline presupposes the existence of administrative organs of state, i.e., of law makers and appliers that are neither the ordinary courts nor the legislature. Conversely, inasmuch as any branch of any government can act only through

*The paper is scheduled to appear in the May 1951 issue of the Michigan Law Review.

law, the assumption of an administrative branch of government can be based only on the existence of administrative law. Despite the fact, however, that the United States and England were the first countries that translated the separation idea into practice, administrative law was recognized in the Anglo-American world as worthy of distinct treatment later than elsewhere, because here the separation doctrine was strongly restricted by the so-called rule of law (or supremacy of law) idea, which the judiciary rendered synonymous with "supremacy of the judiciary." In recent decades the force of this theory has been somewhat diminished.

The separation doctrine can be traced from the establishment of an independent judiciary in England around 1700, Locke's Treatises, and Montesquieu's *Spirit*. The Fathers were influenced by both authors, yet the Constitution is silent on separation. It makes it clear that there are to be three branches of government, but does not state the exact functions of the executive. The Chief Executive is to execute the laws faithfully - what laws, and by what means are they to be executed? How is his function in executing the laws differ from that of the courts, which essentially do the same? It took a long road of both judicial and executive as well as legislative fumbling for the "true" answer to these questions. The solution is largely what might be called a pragmatic one. Matters that are by law assigned to the executive (or which is the same, administrative) branch are administrative, while those not so assigned are either legislative or judicial. Very few distinctions are maintainable upon general and abstract rather than positive-legal grounds.

MATHEMATICS SECTION

Chairman: D. P. Richardson, University of Arkansas

M-1-39

A Note on Two Quadratics. D. M. Seward, Ouachita College.

The point of this paper is the proof of the following Theorem:

There is, in general, no plane collineation which reduces two quadratic forms in three variables to forms containing only squared terms.

M-2-40

Measure Preserving Transformations in the Tensor and Spinor Calculus. G. S. Hewitt, University of Arkansas.

A transformation is called measure-preserving if it leaves outer and inner measure invariant and preserves measurability. Invariance of measure under transformation is investigated for transformations in the theory of relativity and quantum mechanics.

M-5-43

An Inversion Problem in Scattering Theory. H. M. Schwartz, University of Arkansas.

The intriguing question of the possibility of determining under certain conditions the scattering potential from a knowledge of the elastic scattering cross sections is reducible to the following mathematical problem. Suppose it is given that the solution u(r) of the differential equation (and boundary conditions)

$$u''(r) + [k^2 - V(r)]u(r) = 0 \; ; \quad u(0) = 0, \quad u'(0) = 1 \qquad (1)$$

has the asymptotic behaviour:

$$u(r) \sim A(k) \sin[kr + D(k)], \quad r \to \infty \qquad (k \geq 0) \qquad (2)$$

It is known that under certain rather broad conditions on V(r) (2) will hold. The combination of conditions (1) and (2) determine then a unique mapping of the functions V(r) upon the functions D(k) , and the question of the *inversion* of this mapping corresponds to the physical question stated above. Recently Professor N. Levinger of M.I.T. has published interesting results concerning uniqueness of this inversion process. By the use of an iteration process involving integral equations of the first kind it will be shown how this inversion can actually be carried out under certain conditions.

PHYSICS SECTION

Chairman: P. C. Sharrah, University of Arkansas

P-2-48

Theory of the Electron. G. S. Hewitt, University of Arkansas.

Recent investigation in spectroscopic measurements have led to a reinvestigation of the

nature of the electron. A historical survey is made of the classical electron theory, the quantum theory of the electron, and quantum relativistic electrodynamics.

P-5-51

Eliminating Cook-Book Procedures in General Physics Laboratory. O. C. Bates, Henderson State Teachers College.

A report from a physics teacher on his efforts to make the General Physics Laboratory contribute more to the mastery of the fundamental concepts of elementary physics. The "cook-book" directions as furnished by published laboratory manuals, or more often furnished in mimeograph form by the instructor, are not used. Laboratory work is integrated into the regular course work by the student preparing a work sheet describing how he presumes to use the apparatus available to verify some principle or law.

P-8-54

The Mascope, A New Analytic Instrument. Willard H. Bennett, University of Arkansas.

The mass spectrometer is rapidly becoming one of the most important analytic instruments not only to chemists but also for researchers in the various biological sciences because of its ability to measure separately each isotope of each element present regardless of chemical properties. Its importance in the petroleum industry and in the chemical industry has been recognized for years. The applications in biology, physiology and medicine are only now beginning to be apparent since non-radioactive enriched isotopes of the commoner elements are becoming available in quantity.

The principal deterrent to these $50,000 instruments being put to use much more widely has been the great expense and intracacy of operation of the magnetic mass spectrometer which is the only kind on the market.

A new kind of mass spectrometer operating on an entirely different principle was recently invented at the National Bureau of Standards and the development of the various forms is being carried forward at the University of Arkansas and other places. This instrument does not use a magnetic field but separates the elements and their isotopes by a radio-frequency velocity selection.

The instrument is inherently about 10,000 times as sensitive as any previous mass spectrometer and makes rapid scanning of a complete mass spectrum practical for the first time. In this form the instrument is called a "mascope".

This greatly increased sensitivity also makes possible a great simplification of the mass spectra of complex organic molecules by reducing the ionizing voltage and avoiding molecular fragment formation.

The instrument is much simpler and rugged than any previous mass spectrometer, and it is estimated that a manufacturer ought to be able to put it on the market at less than $5,000 in a form usable for general analytic purposes.

SOCIOLOGY SECTION

Chairman: T. C. Cothran, A., M. & N. College

S-2-62

UNESCO: Its Program and Significance. J. L. Stone, Arkansas Agricultural and Mechanical College.

UNESCO is a specialized agency of the Economic and Social Council, one of the six organs of the United Nations. It came into official existence, November 16, 1945, London. On September 1, 1950, there were fifty-nine member states. The head-quarters are at UNESCO House, Paris. Mr. Jaime T. Bodet of Mexico is now Director-General.

UNESCO holds annual meetings and works through National Commissions or cooperating bodies of the member states. It promotes the spread of education, science, and culture in each country. It seeks to eliminate illiteracy, improve health and living conditions, promote the free flow and exchange of ideas, knowledge, cultures, and persons. Thus has promoted a cultural democracy, or pluralism, in which nations, races, and groups contribute and share what each has of value. This should promote goodwill and understanding.

The chief significance of UNESCO is that it deals with the fundamental causes of war. As war begins in the minds of men, so it seeks to construct the defenses of peace in the minds of men.

S-5-65

The State: A Sociological or a Juridical Entity? Reginald Parker, University of Arkansas.

A definition of the term "state" is made difficult by the fact that in common parlance

this term denotes a variety of objects. Thus it has been asserted that the state is not merely a juristic entity - as it unquestionably is - but also a sociological one, that is, an existing social reality independent of its legal order or at any rate not identical with it.

This allegation could be substantiated only by showing that the individuals that belong to one state do on the one hand form a unity and that on the other hand this unity is not constituted by the legal order but by an element other than law. In other words, it is asserted that law is nothing but one of the many elements of the state while its community of human beings is another one.

However, a more careful scrutiny of the meaning of these assertions demonstrates their untenability. It is of course true that one may speak of a unit of people where one influences the others and is in turn influenced by the others. However, it is equally true that all human beings - or indeed all living beings - so interact, and that this interaction takes place quite regardless of their forming a state. Members of a gang of robbers are sociologically influencing and even coercing one another as do groups belonging to different states. The American way of living influences Canadians, and Hitler was regarded as the true leader by many persons of German origin outside of Germany. The state, however, is a normative order and only as such can it be a binding authority. To refer to the inhabitants of a given territory as politically organized people is synonymous to saying that they live in, or indeed are, a state. It is a creation and execution of the legal order and any other criterion fails to give the *differentia specifica* between simple groups of human beings - de facto groups such non-legally organized clubs, members of the same religion, or races - and the state.

There is no sociological concept of the state different from the concept of the legal order. Social reality can be described without using the term "state" and the latter cannot be described other than as a synonym of the legal order.

SCIENCE EDUCATION SECTION

Chairman: B. H. Gundlach, University of Arkansas

SE-3-68

A Simple Laboratory Power Supply. C. Allen, University of Arkansas.

Concerning the construction, approximate cost, and uses of a laboratory power supply for use in a science class.

Output voltage: 6.3 volts A.C. and 0 - 400 volts D.C. with use of powerstat or variable transformer. (Estimated cost without powerstat: $13.00).

SE-4-69

Demonstration Techniques with Home-Built Equipment. John A. Doughty, University of Arkansas.

Demonstration and experimental teaching is often impeded by a shortage of equipment. Some ideas and sources of ideas for constructing home-made equipment are given. Methods of indicating, amplifying, and measuring variables are presented. A frame useful in many demonstrations, a simple electrophorus, and a bimetal strip taken from a fluorescent light starter are demonstrated.

ON TWO NEW SPECIES AND NEW DISTRIBUTION RECORDS OF PARAIULID MILLIPEDS FROM THE EASTERN UNITED STATES

NELL B. CAUSEY

Fayetteville, Arkansas

Millipeds of family Paraiulidae are known from North America and Eastern Asia, with 26 genera and approximately 113 species occurring in the United States and Canada. In the United States the family is best known from east of the Mississippi River, but much remains to be learned about range of species, variation within a species, and the taxonomic characters of females. Several of the species described by H. C. Wood and Charles H. Bollman from this area have never been reported since their initial collection. There are undoubtedly others that are undescribed.

The distribution within a state is perhaps best known in Ohio, where Williams and Hefner (1928) collected 8 species. I have identified the following 7 species from Illinois: *Oriulus venustus* (Wood), *Hakiulus diversifrons* (Wood), *Aliulus rugosus* (Bollman), *Ptyoiulus ectenes* (Bollman), *Illiulus illinoensis* Causey, *Uroblaniulus sandersoni* Causey, and *Aniulus bollmani*, new name; another species of *Uroblaniulus* occurs in counties of Indiana bordering Illinois and may be found in Illinois.

Many of the specimens studied during the preparation of this paper are in the collection of the Illinois Natural History Survey and were made available to me through the kindness of Dr. Milton W. Sanderson. The holotypes of *Aniulus orientalis* and *Uroblaniulus stolidus* will be deposited in the American Museum of Natural History.

Genus *Aniulus*

Chamberlin 1940. Bull. U. Utah. 30(11):3.

Aniulus bollmani, nomen novum

Julus impressus Say [*nomen nudum*] 1821. Jour. Acad. Nat. Sci. Phila. 2(1):102.
Iulus venustus Wood [*partim*] 1864. *Ibid.* (1864):10; 1865, Myr. N. Amer., 196, fig. 29.
Parajulus impressus (Say). Bollman, 1887, Ann. N. Y. Acad. Sci. 4:24; 1893, Myr. N. Amer., 52, 144.
Parajulus venustus (Wood). Bollman, *ibid.* 183.
Parajulus venustus (Wood). Brolemann, 1922, Ann. Ent. Soc. Amer. 15:295, figs. 43-50
[*non*] *Parajulus impressus* (Say). Brolemann, 1922, *ibid.*, 294, figs. 35-42.
Parajulus impressus (Say). Williams & Hefner, 1928, Ohio Biol. Sur., Bull. 18, 127, fig. 21.
Parajulus impressus (Say). Hefner, 1929, J. Morph. & Phys. 48(1):153-163, 4 pls.
[?] *Aniulus impressus* (Say). Chamberlin, 1940, Bull. U. Utah. 30(11):3.
Aniulus venustus (Wood). Chamberlin, 1947, Proc. Acad. Nat. Sci. Phila. 99:36.
Aniulus impressus (Say). Causey, 1950, Proc. Ark. Acad. Sci. 3:46, figs. 7, 8.

Some of the 14 millipeds described by Thomas Say were collected in Florida, others in Pennsylvania or from states in between. Unfortunately, he gave no locality for *J. impressus*, the only species of family Paraiulidae described by him, but later authors (Wood, 1865; Bollman, 1887, 1893) somehow deduced that either Georgia or Florida was the type locality. Since the description contains no specific characters, it can be assumed that Say believed that all of the paraiulids which he encountered - and there are several in the area from which his collections were made - to be one species. For these reasons *J. impressus* Say must become a *nomen nudum* as of 1821. *Aliulus bollmani, nomen novum*, is hence proposed for a widely distributed and perhaps the best known Middle Western milliped, to which the trivial names *impressus* and *venustus* have been applied for almost three-quarters of a century.

H. C. Wood (1864, 1865) confused two species of Illinois paraiulids, as pointed out by Hefner (1929, p. 154). In his description of *venustus*, he showed

figures of the male gonopods of *venustus* (1865, p. 197, figs. 26-28) and the female genital apparatus (*ibid.*, fig. 29) of another and more common species. That Wood was aware of some of this confusion is indicated by the following statement:

> "It is most probable that *I. venustus*, Wood, is the species intended to be indicated by Mr. Say under the name of *impressus*, although his description is so meagre that it could be applied to other species. The locality would seem to fix it, however." (*ibid.*, p. 197)

C. H. Bollman (1887, p. 34) adequately described the male of the species that Wood had drawn the female genital apparatus of and he designated it as *impressus* Say, but unfortunately he did not realize that two species were represented in Wood's description of *venustus*. He altered his position in a paper published (1893, p. 183) after his brief, brilliant career, in which he stated, but still erroneously, that "the true *impressus* is found in Indiana, Georgia, and Florida, while *venustus* is found in Colorado, Kansas, Minnesota, Michigan, Illinois, and Indiana."

For his study of female paraiulids, Henry W. Brolemann (1922) used specimens obtained through R. V. Chamberlin. His figures 35-42, labelled *venustus* (Wood), are really the *impressus* of Bollman 1887, and figures 35-42, labelled *impressus* (Say), are a species of *Oriulus*.

Williams and Hefner (1928), Hefner (1929), and Causey (1950) applied the trivial name of *impressus* to the species, and Chamberlin (1947) has usually used *venustus*.

Aniulus bollmani is thus to be applied to the milliped which has most often been determined as *Aniulus impressus* (Say), after Bollman, 1887, who described the male, and Wood, 1864, 1865, the female. It is distinct from *Oriulus venustus* (Wood), as clearly indicated by Wood's figures of the anterior gonopods of *venustus*. It can be identified by the coxal lobes of the male gonopods, which are in the form of irregular, chitinous plates, each rolled medially in the vertical plane to form a partially closed tube; also of specific value is the serrated inner curvature of the seminal blade of the posterior gonopods; normally the seminal blades are contiguous medially, but they do not cross each other. The species has been identified by the writer from the following states: Ohio, Indiana, Illinois, Michigan, Minnesota, Wisconsin, and North Dakota; it probably occurs also in Pennsylvania. Its frequent occurence in fields of corn in dry weather has led to the common name of corn milliped.

Aniulus orientalis, n. sp.

Figures 1-4

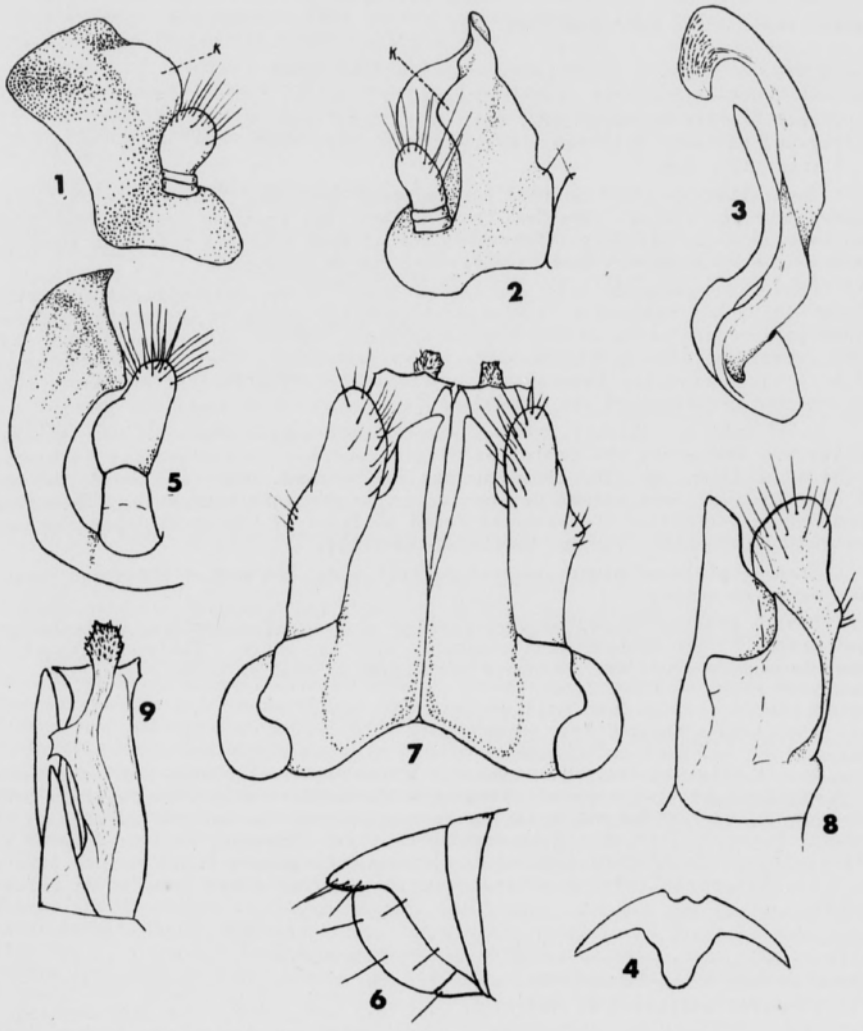
One of the smaller members of the genus, with the male gonopods nearest those of *An. bollmani*; distinguished from *bollmani* by the absence of serrations along the inner curvature of the seminal blades and by the coxal lobes, which together form a single cuplike-like structure, much as in *A. adelphus* Chamberlin 1940, rather than two open tubes.

Male holotype.--Lateral margins of collum wide and straight, each with one entire sulcus and a partial one. Vertical segmental sutures about the diameter of the pores from the pores and weakly curved. Anal spine straight, extending slightly beyond anal valves. Sternal plate of eighth segment triangular, extending almost to the posterior margin of the anterior gonopods (Fig. 4).

Femur of anterior gonopods of the usual shape and size; coxal lobe relatively larger than in *bollmani*, laminate, roughly rectangular, with a keel on the anterio-lateral surface (Figs. 1, 2, k), the mesial surface smooth and concave. Each posterior gonopod (Fig. 3) consists of a flattened seminal blade, sigmoidally curved, and of a shorter accessory blade. *In situ* the coxal lobes are almost vertical, the two forming a single large cup, open ventrad and caudad, around the posterior gonopods; the seminal blades are subvertical, contiguous, or approximately so near their apices, and the accessory blades probably cross at the middle as in *adelphus*.

Diameter 1.5 mm.

Locality probably Durham, North Carolina; 2 males collected Dec. 9, 1939; N. Causey.



Explanation of Figures

Aniulus orientalis, male paratype.

Fig. 1. Left anterior gonopod, lateral view; k, keel on coxal lobe.
Fig. 2. Same, cephalic view.
Fig. 3. Right posterior gonopod, mesial view.
Fig. 4. Sternal process of eighth segment.

Aliulus rugosus (Bollman), male.

Fig. 5. Left anterior gonopod, lateral view.

Uroblaniulus stolidus, male holotype.

Fig. 6. Posterior segments.
Fig. 7. Gonopods, ventral view.
Fig. 8. Left anterior gonopod, dorsal view.
Fig. 9. Left posterior gonopod, dorsal view.

Genus *Aliulus*

Causey 1950. Proc. Ark. Acad. Sci. 3:1.

Aliulus rugosus (Bollman)

Figure 5

Parajulus rugosus Bollman, 1887, Ent. Amer. 3:81 (Myr. N. A., 70, 105).
P. rugosus Bollman. Williams & Hefner, 1928, Ohio Biol. Sur. Bull. 18, p. 127, figs. 19C, 20A.

The following notes on this rare species were made from a male of 56 segments, diameter 2.6 mm, from Owen Co., Indiana, and from two females from Putnam and Calhoun Cos., Illinois. Determination of both sexes is made with some reservation until specimens from Pennsylvania can be studied.

Posterior gonopods very similar to those of the genotype, *Al. carrollus* Causey 1950, but instead of a minute subterminal tooth on the seminal blades, there is a minute notch in the ventral margin. Seminal blades contiguous medially, where they are flattened vertically; just behind the coxal lobes the end of each turns abruptly laterad and horizontally. The shorter accessory blade follows the curvature of the seminal blade.

Coxal lobe of anterior gonopods simple, subtriangular in outline, thickened at the tip and along the posterior margin, and with a distinctive horizontal ridge ectad (Fig. 5). The broad surface of the coxal lobe is outward, and both it and the femur are almost perpendicular to the main body axis. This is in contrast to *carrollus*, in which the broad surfaces of the coxal lobes are horizontal and the cleft ends are contiguous medially.

Sternal piece of eighth segment of male wide, the medial extension tonguelike as in *carrollus*.

Female genital apparatus very similar to that of *carrollus*, with the ventral margin of the synoperculum unusually wide and rough. The sternites of the third segment are cut off obliquely and higher up than in other paraiulids.

Genus *Illiulus*, emend.

Causey 1950, Proc. Ark. Acad. Sci. 3:47.

In the original description of this genus is the statement that "the posterior gonopods have no separate accessory blade, that structure probably being represented by a ridge which arises at the base of the lateral surface of the seminal blade." This should be emended to read: Proximal half or more of accessory blade fused with seminal blade, appearing as a ridge on the lateral surface; the distal region of accessory blade simple and free as in related genera.

Illiulus illinoensis

Causey 1950, *ibid.*, figs. 13-17.

In males collected in Jefferson and Yell Cos., Ark., the free portion of the accessory blade has a diameter of about one-third that of the seminal blade at the point where they diverge; the accessory blade continues ventrad vertically, the apex reaching slightly below the lowest level of the outer curvature of the seminal blade. These specimens differ slightly from the holotype in that the coxal lobes are a little longer and are without the slight undulations in the lateral margins.

Genus *Uroblaniulus*

Uroblaniulus Attems. Chamberlin and Hoffman, 1950, Nat. Hist. Misc., No. 71, 6.

Uroblaniulus stolidus, n. sp.

Figures 6-9

This species is near *dux* (Chamberlin 1914). It differs from *dux* in that the femora of the anteroir gonopods are not broad, the femora and coxal pieces are almost of the same length, and the coxal pieces do not "enlarge again a little," nor are they "distally subtruncate;" unlike *dux*, the posterior gonopods do extend beyond the anterior. Anal spine shorter than in any other species of the genus and not curved.

Male holotype.- Lateral margin of collum with three entire sulci on one side and two on the other. Eyes subtriangular, ocelli in 6 rows, 9 or 10 to 3 ocelli in each row. Anal spine stout and short (Fig. 6).

Femora of anterior gonopods weakly clavate, setae arranged in two areas (Fig. 7). Coxal pieces slightly excavated medially, abruptly narrowed distad, the apices obliquely truncate and almost as long as femora. Dorsally the coxal pieces have the usual lateral and medial folds (Fig. 8), the shape distinctive for the species.

Each posterior gonopod consists of four longitudinal pieces (Fig. 9): ventrad are the medial, narrow piece and the lateral main piece with its distal margin almost straight; dorsad are the medial, short piece and the long column, which is longitudinally striate, finely pubescent distally, and the longest piece of the four. In ventral view the posterior gonopods are visible between and beyond the anterior.

Diameter 1.6 mm., 46 segments, last 3 legless.

Type locality.- Penninsula State Park, Door Co., Wisc.; one male Sept. 29, 1951; Dr. and Mrs. H. W. Levi.

Several specimens of *U. immaculatus* (Wood) were collected by the Levis the same day from the same general locality.

Genus *Ptyoiulus*, emend.

Chamberlin 1940, Bull. U. Utah 30 (11):15.

In all known species the posterior gonopod has a basal accessory branch.

Ptyoiulus ectenes (Bollman)

Parajulus ectenes Bollman, 1887, Proc. U. S. Nat. Mus. 10:617 (Myr. N. A., 34).
Ptyoiulus coveanus Chamberlin, 1943, Bull. U. Utah 34(6):10, figs. 24-25.

When Bollman wrote that the male genitalia of *ectenes* are entirely different from those of *pennsylvanicus* (Brandt), he obviously meant to imply only that the two species are separable on the basis of the genitalia. Specimens of *ectenes* from Raleigh and Durham, N. C., correspond with Bollman's description of the types except that the anal spine passes beyond the anal valves, as in other species of the genus. The gonopods are distinguished from those of *pennsylvanicus* and *georgiensis* Chamb. 1943 collected at Rockaway, N. J., and Blount Co., Ala., respectively, principally by the type of setae on the femora, the shape of the corolla, and the shape of the posterior gonopods. The setae on the ventral surface of the distal region of the femora are, in *pennsylvanicus* and *georgiensis*, of two types: medially there is an area of evenly short, fur-like setae; laterad the setae are of uneven length, but longer; between the two areas is a short, longitudinal, glabrous ridge. In *ectenes* there is no fur-like area, the setae are of irregular length, and there is no longitudinal ridge. The corolla differs from that in other species in that it is smaller, flares less, it is not striated, the margin is not serrated, and it is cut away to the base dorsally; inside the corolla, the apex is blunt rather than sharp and hooked. The main piece of the posterior gonopods differs from that in other species in that the distal enlargement is smaller; the crook shown by Chamberlin (1943, fig. 25) appears when the piece dries. In *ectenes* the lateral margin of the distal half of the penial plate are concave; in other species they are convex.

Specimens of *ectenes* in the collection of the Illinois Natural History Survey are from Goodlettsville, Tenn., and from Pope, Hardin, and Gallatin Cos., Ill. Diameter of adult specimens is from 1.5 to 1.7 mm.

THE TERRESTRIAL ISOPODA OF ARKANSAS*

DAVID CAUSEY

University of Arkansas

1. Introduction

The Isopoda are an interesting and readily available example of one division of the higher crustacea. After the caridoid facies became established in the early Malacostraca, two divergent trends arose. In the Eucarida, e.g., the shrimp, crawfish, and crab, the trend included the elaboration of the carapace into a myriad pattern of forms, sculpturing, and coloring, along with the emphasis on stalked eyes and the carrying of the eggs by the female on her abdominal appendages. In the Percarida, on the other hand, there is a progressive reduction of the carapace until in the higher members of the group-- the Amphipoda and the Isopoda-- it has been lost; and the presence of sessile eyes and the carrying of the eggs and young by the female in a brood chamber formed by inward extensions of the thoracic appendages are characteristic.

True to the general nature of the class to which they belong, the Isopoda have shown great powers of exploiting the environmental opportunities. They are fundamentally marine and littoral, but have radiated out in many directions. Many are the "cockroaches" of the seashore, cleaning up whatever organic matter comes their way. Still more have become parasitic upon a variety of hosts, especially other crustaceans and fish. Some, including gigantic forms nearly a foot long, are found on the bottom of the deeper sea. Many have invaded the freshwaters, and a relatively few have become terrestrial. These, "the insects of the crustacean world" (Hatch), have established a relatively feeble hold upon the habitat, but where favorable nitches offer the right moisture conditions and food, they thrive in numbers sufficient to attract attention and to receive common names. "Their color has caused them to be likened to little asses, and their crowding together to little pigs" (Hatch) and their small size and activities have suggested lice, hence such names as *Asellus*, sow bug, and wood louse. Other names are pig louse, "millipede," and "pill-millipede." Slater, because of the color of many is appropriate but not widely used. In Arkansas they seem to be referred to as sow bug, pill bug, and certain kinds are called rolly-polly bugs. Some 21 terrestrial species occur in North America, 14 species from the Middle Atlantic States (New York to Virginia), 9 species in Connecticutt, 19 from the Pacific North West (Hatch), and 10 from Michigan (Hatchett). This paper reports 9 species from Arkansas.

The literature on the Isopoda is relatively enormous. The standard reference for American forms is Harriet Richardson's A Monograph on the Isopods of North America (1905). The most comprehensive later work is Van Name's The American Land and Fresh-water Isopod Crustacea (1936) with two supplements. Of the shorter works, Hatch, The Chelifera and Isopoda of Washington and Adjacent Regions (1947), and Hatchett, The Biology of the Isopoda of Michigan (1947) are recent and excellent. Little mention of Arkansas isopods occurs in the literature. Fitch (1855) reported *Porcellio immaculatus* (now *Porcellionides pruinosa*) from Arkansas, and this is repeated in Underwood's (1886) check list. One infers the presence of a few species in Arkansas from such statements as southern United States, etc.

2. Life History

Little is known as to the general biology of the American terrestrial isopods. Hatchett's Michigan studies are the most recent and thorough and are freely paraphrased in the following. The female is called gravid when carrying eggs, embryos, or young in the brood pouch (marsupium). This period is variable -- for four different species of as many genera Hatchett reports averages of 39, 43, 43.5, and 52 days. Also variable is the number of broods per year, commonly one, often two, and occasionally three. He reports from 10 to 70 in a brood for one species.

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The young commonly leave the brood pouch at the anterior end or slip between the gaps in the oostegites. In emergencies, as when the mother is being disturbed, she may discharge them herself. The young usually have the first molt within 24 hours after leaving the mother, and the second occurs within the first two weeks. Most have a third molt in the third week. The majority molt a fourth time within the fifth week. Hatchett found that from there on the young tended to molt every two weeks until they were about 20 weeks old. After this, the molting is irregular, and dependent upon the food supply. The isopods probably average two years of life, with a few reported to have lived for five years. No such data are available at present for the Arkansas species. The only study of a nearby area appears to be that of Pierce (1907) upon *A. vulgare* near Dallas, Texas.

3. Economic Importance

The terrestrial isopods are found in damp places where they live on the decaying organic material, largely plant, which is available. Under some circumstances, where moisture and food are abundant, they increase in numbers to an extent which attracts attention and may be annoying, either from an esthetic viewpoint for those who don't like crawling forms of life, or from being somewhat of a nuisance, such as being crushed under foot and so being messy. In the south they sometimes damage growing plants such as cotton and the common garden vegetables. Ornamental plants such as violets and rhododendron seedlings are sometimes attacked. In greenhouses they often are both a nuisance and a source of damage to plants. Dusting with arsenates or the use of poisoned baits are recommended.

Probably due to the famous doctrine of signatures in materia medica, *Armadillidium vulgare*, a very common old world form which rolls up and looks like a large pill, has been used either dried and powdered or as a wine of millipedes in medicine for various ailments. Fitch (1855) reported that they had been dropped from the pharmacopaeias, but Bate and Westwood (1868) mention that "they are still taken medicinally in some parts of Somersetshire." In my childhood a half dozen or so sewed in a little cloth bag and suspended about a child's neck was a sure preventative for the croup. So far as I can recall it was as effective as wearing a lead nickel in the same way to prevent nose bleed!

4. Distribution of Species

Bate and Westwood (1868) reported that "Of fourteen species described by Professor Kinahan in his memoir on this family ... he states that all, except two (one a marine species), had been found by him in a garden not sixty yards square, and nearly all in abundance." This is certainly not true for Arkansas. During our collecting trips the past several years we have rarely found isopods, although looking in sites-- under and in logs and under rocks-- where we expected to find them. Many trips during which numerous millipedes and earthworms were found failed to turn up a single isopod. In Arkansas *A. vulgare* is commonest in the vicinity of habitations, and is common is compost heaps, basements and in damp areas (e.g. under boards or rocks) in yards. This species occurs in the ivy on our house foundation and on the fireplace chimney which is ivy covered from the ground to the top.

The majority of the collections were made by Dr. Nell Bevel Causey and the author. Graduate students who have brought specimens include Miss Ruth Steuart, Clarksville, and Mr. Newton R. Pillstrom, Altus. Professor Walter Harman, of Louisiana Polytechnic Institution, Rustan, La. has sent me a number of specimens from El Dorado. I express my thanks to all of these.

The following data are admittedly incomplete, for with only limited time for collecting, and that highly seasonable, there are areas from which I have no specimens. Most of the data apply to the western half of the state; the northwestern portion has been most thoroughly examined. Efforts to collect isopods in the north eastern quarter of the state have been fruitless thus far, and no opportunity to collect in the south eastern quarter of the state has occurred.

Armadillidium nasatum:

Fayetteville, Washington County. Widespread over the area, but apparently less common than *A. vulgare*, with which it often occurs. Very scanty data suggest the ratio of *A. nasatum* to *A. vulgare* is about 1:5 in the Fayetteville area.

Mt. Magazine, Logan County.

Armadillidium vulgare:
Altus, Franklin County.
Blue Springs, Carroll County.
Camp Chaffee, Ft. Smith, Sebastian County.
Cave Springs, Benton County.
Clarksville, Johnson County.
El Dorado, Union County.
Fayetteville, Washington County.
King's River, Carroll County.
Lake Leatherwood, Carroll County.
Monte Ne, Benton County.
Pine Bluff, Jefferson County.
Texarkana, Miller County.
This, the commonest species in Arkansas, according to present data, is common around buildings and in greenhouses.

Ligidium longicaudatum:
Cave Springs, Benton County.
Monte Ne, Benton County.
Mt. Magazine, Logan County.
This species is the only Arkansas form which appears to be native American rather than introduced (cf. however, *T. demivirgo*). It does not appear to be common and the records are from areas with little or no man-made changes. While one suspects that this form is unable to withstand competition with the introduced old world forms, no good evidence in favor of this is available.

Oniscus asellus:
Clarksville, Johnson County.
El Dorado, Union County.
Fayetteville, Kessler Mt., Washington County.
This species tends to be associated with yards and gardens.

Porcellio scaber:
Blue Springs, Carroll County.
Cain Hill, Washington County.
Fayetteville, Washington County.
Lake Leatherwood, Carroll County.
Stamps, Miller County.
This species may be found in basements, and in yards.

Porcellio spinicornis:
Fayetteville, Washington County, including Kessler Mt.
This occurs around houses and on nearby hillsides.

Porcellionides pruinosus:
El Dorado, Union County.
Fayetteville, Kessler Mt., Washington County.
Greenwood, Sebastian County.
This species is associated with houses and nearby hillsides.

Trachelipus (=Tracheoniscus) rathkei:
Fayetteville, Washington County.
King's River, Carroll County.
This appears to occur away from houses and yards, and on hillsides. It has been found with *A. vulgare*.

Trichoniscus demivirgo:
Beaver, Carroll County.
Monte Ne, Benton County.
West Fork, south of, Washington County.
This is to be found associated with punky wood in old logs. It is the smallest of our terrestrial isopods, with only females known to occur in the United States, and if regarded as distinct from the related European species, is another native species.

5. Key to the Terrestrial Isopods (Oniscoidea) of Arkansas (after Hatchett).

This is a conventional dichotomous key in which the user is always presented with a choice of two statements, one of which must be true (one hopes!). If a statement is not true, the one referred to by the figure in parentheses is the alternative. The key applies only to adult specimens. The plate illustrates the characteristics used and the numbers are the same as those of the key.

1 (2) First pair of antennae plainly visible and at least one-fourth as long as second pair of antennae; posterior segments of abdomen fused.

Freshwater Isopoda (not considered in this key).

2 (1) First pair of antennae inconspicuous, rudimentary and not one-fourth as long as second pair; abdominal segments not fused.

Terrestrial Isopoda.....3

3 (6) Uropods not extending beyond the terminal segment of the abdomen..... 4

4 (5) Head with a small V-shaped notch at front end*.....

Armadillidium nasatum

5 (4) Head without such a notch.....

Armadillidium vulgare

6 (3) Uropods extending beyond the terminal segment of abdomen 7

7 (10) Flagella of antennae (actually the second pair because the first are rudimentary) of 4 to many segments..... 8

8 (9) Flagella of antennae of 4 or 5 segments.....

Trichoniscus demivirgo

9 (8) Flagella of antennae with more than 5 segments.....

Ligidium longicaudatum

10 (7) Flagella of antennae with either 2 or 3 segments..... 11

11 (12) Flagella of antennae with 3 segments.....

Oniscus asellus.

12 (11) Flagella of antennae with 2 segments..... 13

13 (14) Abdomen abruptly narrower than thorax; antennae conspicuously banded with white at joints.....

Porcellionides pruinosus

14 (13) Abdomen and antennae not so..... 15

15 (16) Dorsal surface of head rough, but not conspicuously tuberculated.....

Trachelipus (= Tracheoniscus) rathkei

16 (15) Dorsal surface of head with many conspicuous tubercles.. 17

17 (18) Dorsal surface of body conspicuously tuberculated.....

Porcellio scaber.

18 (17) Dorsal surface of body not conspicuously tuberculated...

Porcellio spinicornis.

*"The large, squarish, forwardly extending lobe into which the epistome is produced distinguished this species from *A. vulgare.*" (Van Name).

6. Summary

Nine species of terrestrial isopods are listed from Arkansas: *Armadillidium nasatum, A. vulgare, Ligidium longicaudatum, Oniscus asellus, Porcellio scaber, P. spinicornis, Porcellionides pruinosus, Trachelipus* (= *Tracheoniscus*) *rathkei,* and *Trichoniscus demivirgo.* Their presently known distribution and a key for their identification are given.

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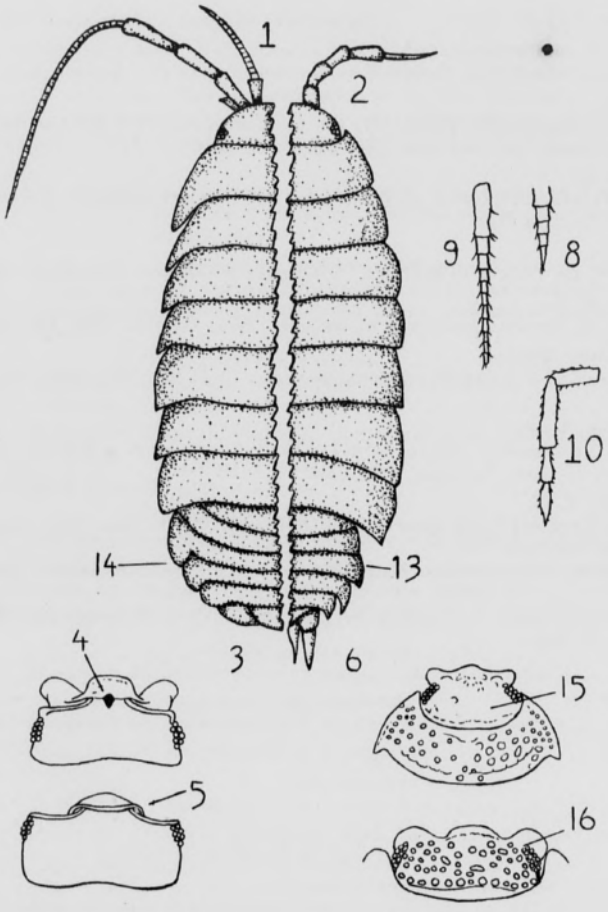

Explanation of Plate

The plate illustrates the characteristics used in the key. Figures with which numerals 4, 5, 15 and 16 are associated are redrawn from Hatch, and 8, 9, and 10 are redrawn from Hatchett. The large diagram of an isopod is a composite of the characteristics indicated.

Fig. 1. The two pairs of antennae characteristic of the aquatic isopoda.
Fig. 2. The readily seen pair of antennae, actually the second pair.
Fig. 3. Uropods not extending beyond the body contour of the terminal abdominal segment.
Fig. 4. Illustrating the small V-shaped notch and the squarish protruding epistome. on the head of *A. nasatum*.
Fig. 5. Illustrating the absence of the V-shaped notch and squarish lobe.
Fig. 6. Uropods extending beyond the terminal segment of the abdomen.
Fig. 7. Use figure 9.
Fig. 8. Showing antenna with 4 segments to the flagellum.
Fig. 9. Showing antenna with more than 5 segments to the flagellum.
Fig. 10. Showing antenna with 2 segments on flagellum.
Fig. 11. Use fig. 10, but imagine the flagellum with 3 segments!
Fig. 12. Use fig. 10.
Fig. 13. Showing abdomen abruptly narrower than thorax.
Fig. 14. Showing abodmen not abruptly narrower than thorax.
Fig. 15. Showing dorsal surface of head rough but not conspicuously tuberculated.
Fig. 16. Showing dorsal surface of head conspicuously tuberculated.

THE EARTHWORMS OF ARKANSAS*

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I. Introduction

The terrestrial earthworm, *per se*, needs no introduction. It is *Lumbricus terrestris* in the textbooks and in the freshman laboratory, the *common earthworm* although in sober fact the common earthworm in the United States is either *Allolobophora caliginosa* or *Eisenia foetida*. That there are other earthworms, that some are native and others introduced from other continents appears to be esoteric and confidential.

The literature on the Oligochaeta is large. Beddard's Monograph of the Order of Oligochaeta (1895) covers the literature up to 1894. Following this came Michaelsen's Oligochaeta (1900) which is taxonomical and which has been ably supplemented by Stephenson's The Oligochaeta (1930), which is mainly morphological and biological. In this country Frank Smith devoted much of his professional life to the group, and among his many publications his 1915 and 1917 papers are valuable for taxonomic purposes. Olson's Earthworms of Ohio (1928) is perhaps the most useful to beginners. Later papers of especial interest are Gates' Genus *Pheretima* in North America (1937) and his Check List and Bibliography of N. A. Earthworms (1942), and Eaton's Earthworms of the Northeastern United States (1942).

This admittedly preliminary survey of the terrestrial earthworms of the state is largely incidental to collecting for other purposes. I am indebted first of all to Dr. Nell Bevel Causey for her continual assistance. I am further indebted to the many students who have brought specimens from their home areas. Among these, to whom grateful acknowledgment is due for repeated collections are: Gloria Roensch, Siloam Springs, Ruth Steuart, Clarksville; Sam Gooden, Conway; Newton Pillstrom, Altus; Henry Rogers, Smackover; Jack Walker, Magnolia; and Joseph Wellborn, Osceola. Dr. Thomas De Palma, Fayetteville, has brought many specimens from his "eighty," and I have made some use of a report prepared by Dr. Ruell Sparks, Little Rock, while a graduate student here at the University. Finally, I am indebted to Rev. H. M. Bevel, Junction City, and to Prof. Walter Harman, Louisiana Polytechnic Institution, Ruston, La., for specimens.

An activity which may change the earthworm fauna of an area is the growing of earthworms, either for personal use or for the market. The only *L. terrestris* record I have is due to an introduction for personal use. The Blytheville (Ark) Courier News, May 23, 1951, has an article upon the worm ranch being run by Mr. J. C. Chapin of Manila, whose product is being marketed in Arkansas, Oklahoma, Tennessee, and Texas. Probably other such enterprises exist in the state. Escapes from such projects or the discarding of left over bait will, no doubt, hasten the introduction of certain species.

A sample lot of earthworms kindly furnished me by Mr. Chapin contained six species:

A. Caliginosa t. trapezoides 13 specimens
E. foetida 111 specimens
E. rosea 5 specimens
L. rubellus 13 specimens
P. californica 2 specimens
P. hupeiensis 9 specimens

2. Distribution of Species.

Smith (1915) lists 18 species as present in Illinois, and Olson (1928) lists 20 species for Ohio. Gates' Checklist (1942) allows one to conclude that some 73 species have been described from the United States, a large portion of which are characterized by such statements as "doubtful," "known only from the

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original description," etc. The total number of valid species might reach 50, with somewhere between 30 and 40 being more probable.

The present paper reports 17 species, scattered among 9 genera. Of these 6 species are regarded as native to the United States, 8 are introduced European forms, and 3 are Asiatic in origin. The latter, the *Pheretimas*, are so adaptable that it would appear that they are already the most common earthworm in some parts of the southern half of the state, and are to be found in practically all of the state. As has been pointed out repeatedly by investigators, our native worms seem to be losing out in the competition with foreign species, and are being replaced by European species in the north. In the south the genus *Pheretima* seems to be the successful invader. The conflict between the European forms and the Asiatic *Pheretima* on American soil should prove to be an interesting struggle in the years to come.

Allolobophora caliginosa f. typica:
Altus, Franklin County.
Conway, Faulkner County.
Danville, Yell County.
Fayetteville, Washington County.
Pine Bluff, Jefferson County.

Allolobophora caliginosa f. trapezoides:
Alix, Johnson County.
Altus, Franklin County.
Clarksville, Johnson County.
Danville, Yell County.
Eureka Springs, Carroll County.
Fayetteville, Washington County.
Manila, Mississippi County.
North Little Rock, Pulaski County.
Smackover, Union County.
West Fork, Washington County.

Stephenson (1930) considers this "perhaps the commonest of all earthworms, taking the world into consideration," and Smith (1917) says, "There is scarcely one of the United States in which collections have been made in which this species is not found abundantly represented."

The two types are separated upon differences in the tubercula pubertatis, in *typica* they are separate swellings on 31 and 33, in *trapezoides* they form ridges from 31 to 33. "In many specimens it is difficult to decide which condition is present, and the two forms very generally occur together... Again I do not believe that these differences have subspecific value, since neither in Europe nor in America are they geographically significant, but suggest that one or more pairs of genetic allelomorphs may be responsible, the proportions varying among different populations of the species (Eaton)."

This species occurs in cultivated soils, lawns and gardens, woodlots, etc. It is an introduced European form.

Bimastos beddardi:
Fayetteville, Washington County, on Mt. Sequoyah.
Magnolia, Columbia County.
This species, according to Smith (1917) occurs in "wet situations, and in decaying logs, stumps, or moss." My collections are from wooded areas, "millipede territory," and I would expect it to be found more frequently than my records indicate. It is a native species.

Bimastos longicinctus:
Fayetteville, Washington County.
Little Rock, Pulaski County.
This native species was first described from Illinois and later from Ohio. I add it from Dr. Sparks' report. Occurs in garden soil and prairie region east of Little Rock.

Bimastos parvus:
Lake Leatherwood, Carroll County.
My specimens are from a wooded north side of a hill. This is a native species.

Dendrobaena octaedra:
Fayetteville, Washington County, on Mt. Sequoyah.
In a wooded area, formerly cultivated. This is an introduced European species.

Diplocardia communis:
Fayetteville, Washington County.
Siloam Springs, Benton County, from King Ranch, in garden soil.
This is a native species, and probably common.

Diplocardia riparia:
Osceola, Mississippi County. *Pheretima* occurred in the same collection.
Siloam Springs, Benton County, from King Ranch, in garden soil.

Diplocardia singularis:
Beaver, Carroll County. With *E. foetida*.
Conway, Faulkner County.
El Dorado, Union County.
Fayetteville, Washington County.
Mt. Magazine, Logan County.
Smackover, Union County.
This native species appears to be widespread. It comes from both cultivated soils such as gardens and lawns, and from relatively undisturbed soils in wooded areas.

Eisenia foetida:
Beaver, Carroll County. With *D. singularis*
Junction City, Union County.
Magnolia, Columbia County.
Manila, Mississippi County.
Smackover, Union County.
This is an introduced European form. It is found in cultivated areas and in decaying logs.

Eisenia rosea:
Fayetteville, Washington County, on Mt. Sequoyah.
Manila, Mississippi County.
This is an introduced European form, wide spread in the United States and no doubt common in Arkansas.

Eiseniella tetraedra:
Eureka Springs, Carroll County.
This introduced European form is widespread in the United States, and should be common in cultivated soils in Arkansas near creek banks, etc. My sole record is from Dr. Sparks' report. There are many varieties reported, which according to Eaton (1942) "Probably the difference is due to assortment of genetic allelomorphs."

Lumbricus rubellus:
Manila, Mississippi County.
Dr. Sparks' report lists this as "quite common and widely distributed," which I take to mean in N. W. Arkansas. It is an introduced European form.

Lumbricus terrestris:
Conway, Faulkner County.
My single record of this is based on a specimen brought to me by Mr. Sam Gooden, who had purchased them to start a worm bed for fishing purposes. This species, an introduction from Europe, is readily established and should be common in the older cultivated areas of the state. I would also expect it to be a species of choice by commercial growers.

Octolasium lacteum:
Beaver, Carroll County.
Weddington, Washington County.
West Fork, Washington County.
In leaf mold and detritus on hill sides. Generally considered to prefer moist and rich organic material. It is an introduced European form.

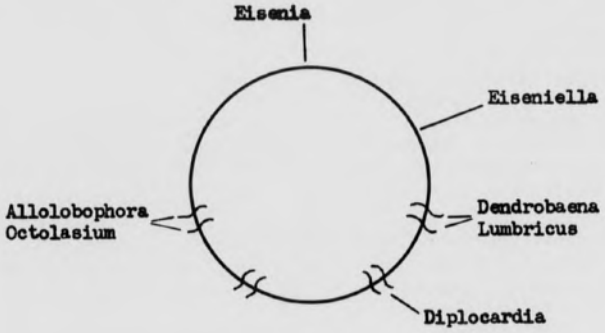
Pheretima californica:
Manila, Mississippi County.

Pheretima diffringes:
Little Rock, Pulaski County, in Boyle State Park.

Pheretima hupeiensis:
Fayetteville, Washington County.
Junction City, Union County.
Manila, Mississippi County.

This is the most widespread species of the genus in the state, according to my present records.

I have little doubt that more extensive collecting will disclose that this very successful genus is represented by a number of additional species. Gates' (1937) checklist indicates that we are in the probable range of *P. hawayana* and *P. morrisi*.



Text Figure A.

Text Figure A. The circle represents the intersegmental groove, and the setae could not be as represented. The approximate location of the spermathecal pores for the several genera. *Bimastus* has none, and the *Pheretima* species listed have pores which are on the segments, near the anterior border of the segments and ventrad.

3. Keys for Identification of Mature Earthworms

Probably there are as many ways of preparing earthworms for study as there are workers. I prefer to anesthetize the worms in about 50% alcohol, and when they become motionless to pile them up like cord wood between two small pieces of plate glass (1/4" x 1" x 6"). With a little experience reasonably straight worms can be prepared. After the worms have died in a straight condition I replace the alcohol with 5% formalin solution. This hardens the worms and the stiffened specimens are much easier to handle.

Although two keys are included, I find the tabular key much the faster. In the formal, systematic key one may be stopped by the inability to determine some characteristic called for. The tabular key presents all critical data at a glance. Some order in noting the characteristics is helpful. If the setae are observed first, the genus *Pheretima* will readily be separated from all the others. Then the position of the clitellum with respect to the number of the somites involved should be determined. This will narrow the possibilities considerabley. I prefer to determine the position of the first dorsal pore next. By now the possibilities will be few and other critical data, such as the openings of the spermathecal pores and the position of the tubercula pubertatis, looked for. Generally a specimen which has been allowed to become almost dry on its surface will show pores better than a moist one. Text figure A is a guide to the location of spermathecal pores with respect to the cross-section of the worm. A broad field dissecting binocular is almost essential if many worms are to be examined. Good artifical light is important. One should be prepared to discover that many specimens cannot be identified by gross examination. Immature ones will require dissection or sectioning. It should not be forgotten

that anomalies occur.

Rough field identification can be made of some. The brown and buff banding of *E. foetida* is readily recognized. The greenish color and pinkish clitellum will identify many *A. chloroticus*, but not all. The larger size of *L. terrestris* and the *Diplocardia* distinguish them from many other species and they themselves can be separated by the general position of the clitellum from the anterior end, its type, and the color of the worms. The *Pheretimas* are pugnacious, snake-like, lashing about vigorously, and if drawn through the fingers are distinctly rougher than our other genera. I suspect that such field characteristics are of more value to the person recommending them than to others!

The following key includes not only the genera and species of earthworms now known to occur in Arkansas, but also a number of species which may be found in the state when more extensive collecting can be done. It follows the keys of Smith (1917) and Eaton (1924). Technical details not referred to in the text are illustrated in the accompanying plate.

Key to Earthworms

1	(48)	Setae arranged in 4 rows of 2 each (lumbricine)..... 2
2	(7)	Clitellum begins at or anterior to 15; spermiducal pores posterior to clitellum. *Diplocardia*..... 3
3	(4)	Clitellum a cingulum (complete ring).
		D. singularis.
4	(3)	Clitellum not a cingulum but saddle-shaped..... 5
5	(6)	Spermathecal pores in 6/7,7/8, and 8/9; anterior dorsal surface pale flesh color.
		D. communis.
6	(5)	Spermathecal pores in 7/8, and 8/9; anterior dorsal surface dark brown color.
		D. riparia.
7	(2)	Clitellum begins back of 15; spermiducal pores anterior to clitellum..... 8
8	(43)	Prostomium does not completely divide the peristomium (epilobic)..... 9
9	(30)	Clitellum begins in front of 30..... 10
10	(11)	Clitellum does not extend posteriorly to 28
		Eiseniella tetraedra and varieties.
11	(10)	Clitellum extends posteriorly at least to 28..... 12
12	(19)	Spermathecal pores dorsal to seta line *d*.
		Eisenia..... 13
13	(14)	Setae widely paired, $ab : bc : cd = 5 : 9 : 5$.
		E. veneta
14	(13)	Setae closely paired..... 15
15	(16)	Spermathecal pores in 8/9, 9/10, and 10/11; clitellum 24-30.
		E. lonnbergi.
16	(15)	Spermathecal pores in 9/10 and 10/11..... 17
17	(18)	Segments transversely banded with brown and buff; clitellum 24, 25, 26-32; tubercula pubertatis 28-30, 31.
		E. foetida.
18	(17)	Segments not so banded; clitellum 24, 25, 26-31, 32, 33; tubercula pubertatis 29-31.
		E. rosea.
19	(12)	Spermathecal pores, if present, in or ventral to seta line *d*..... 20
20	(28)	More than two pairs of sperm sacs (seminal vesicles) present; with seminal receptacles (spermathecae)..... 21
21	(25)	Setae closely paired; sperm sacs in 9 - 12.

Allolobophora..... 22

22 (23,24) Clitellum 27, 28-34, 35; tubercula pubertatis 31-33 or 31 and 33.

A. caliginosa and varieties.

23 (22,24) Clitellum 27, 28-35; tubercula pubertatis 32-34.

A. longa.

24 (22,23) Clitellum 29-37; tubercula pubertatis 31, 33, and 35; greenish color when alive.

A. chlorotica.

25 (21) Setae separate or widely paired; sperm sacs in 9, 11, and 12.

Dendrobaena..... 26

26 (27) Clitellum 25, 26-31, 32; tubercula pubertatis 28-30.

D. subrubicunda.

27 (26) Clitellum 27, 28, 29-33, 34; tubercula pubertatis 31-33.

D. octaedra.

28 (20) Two pairs of sperm sacs present; no spermathecae (or imperfectly developed in *B. tenuis*)

Bimastos..... 29

29 (41) Setae closely paired..... 30

30 (38) Clitellum covers less than 10 segments..... 31

31 (35) Clitellum begins on or in front of 23..... 32

32 (33,34) Clitellum on 23-28.

B. palustris

33 (32,34) Clitellum on 20, 22-29, 30; *ab* greater than *cd.*

B. gieseleri and varieties.

34 (32,33) Clitellum 22-29; *ab* = *cd.*

B. tumidus.

35 (31) Clitellum begins on or behind 24..... 36

36 (37) Clitellum 24-30; tubercula pubertatis (indistinct) 25, 26-29, 30.

B. parvus.

37 (36) Clitellum 24, 25-31; tubercula pubertatis (indistinct) 24, 25-30.

B. beddardi.

38 (30) Clitellum covers 10 or 11 segments..... 39

39 (40) Clitellum 23-32 or 24-33.

B. longicinctus.

40 (39) Clitellum 27-37.

B. zeteki.

41 (29) Setae widely paired

B. tenuis.

42 (9) Clitellum on 30-35; setae widely paired.

Octolasium lacteum.

43 (8) Prostomium completely divides peristomium (tanylobic).

Lumbricus..... 44

44 (47) Clitellum begins on or in front of 28; sperm ducts without distinct papillae..... 45

45 (46) Clitellum 26, 27-32; tubercula pubertatis 28-31.

L. rubellus.

46 (45) Clitellum 28-33; tubercula pubertatis 29-32.

L. castaneus.

47 (44) Clitellum begins behind 28 (actually 31, 32-37); tubercula pubertatis 33-36; sperm ducts with distinct papillae.

L. terrestris.

48 (1) Setae more than 4 rows of 2 each, being in a ring more or less broken in mid-dorsal and mid-ventral lines (perichaetime).

Pheretima..... 49

49 (50,51) With 2 pairs of spermathecal pores, 7/8, 8/9.

P. californica.

50 (49,51) With 3 pairs of spermathecal pores, on anterior margins of 7-9.

P. hupeiensis.

51 (49,50) With 4 pairs of spermathecal pores, 5/6-8/9.

P. diffringes.

4. Glossary of Technical Terms

Formerly there was considerable lack of uniformity in the use of terms and symbols for earthworm taxonomy. Smith (1917) used a system which has been generally followed by subsequent writers, and which is used in this paper. The various terms used are defined in this glossary, and illustrated in the accompanying plate where deemed necessary.

ANNULAR CLITELLUM. Cf. cingulum.

CINGULUM = RING-SHAPED or ANNULAR CLITELLUM. The clitellum forms a complete ring about the body, cf. fig. 4, cing.

CLITELLUM. A completely or incompletely ring-shaped glandular thickening of the body wall in sexually mature worms and extending over several segments.

DORSAL PORES. Small mid-dorsal apertures leading to the body cavity, in the intersegmental grooves.

EPILOBIC PROSTOMIUM. Type in which the peristomium is only partly divided, the folds not reaching groove 1/2, cf. fig. 2, epi.

INTERSEGMENTAL GROOVE. The depression between two segments, generally representing externally the septum within.

LUMBRICINE. With setae in four rows of two each, as in *Lumbricus*, cf. fig. 3, lum.

PERICHAETINE. With more then 8 setae per segment, often 50-100 or more, and arranged in a ring around the segment; usually the ring of setae is more or less broken mid-dorsally and mid-ventrally, cf. fig. 3, pch.

PERISTOMIUM. The first segment, containing the mouth and not bearing setae, cf. fig. 1, per.

PROSTOMIUM. A rounded lobe overhanging the mouth and usually considered a part of the peristomium, cf. fig. 1, pro.

SADDLE-SHAPED CLITELLUM. A ring which is incomplete on the ventral side of the body, cf. fig. 4, sad.

SEGMENTS or SOMITES. Designated by arabic numbers from the anterior and posteriorly. In case of doubt, the second segment is the first to bear setae.

SEPTUM. The internal division which limits the body cavity, and which is more or less indicated externally by the intersegmental groove, cf. fig. 1, s.

SETAE. Lumbricine (8 per segment) or perichaetine (more than 8 per segment); lettered from the ventral-most dorsally, cf. fig. 3. If the distance from *a* to *b* and *c* to *d* is less than 1/3 the distance from *b* to *c* the setae are closely paired, if otherwise they are widely paired, cf. fig. 3. In perichaetine setae they are also lettered from z backwards through the alphabet if reference to the upper ones is necessary, fig. 3.

SPERMATHECAE = SEMINAL RECEPTACLES. Pouches developed in the septa which receive sperm cells from another individual at the time of copulation.

SPERMATHECAL PORES. Openings to the spermathecae.

SPERM SACS = SEMINAL VESICLES. Storage sacs for sperm cells produced by the worm itself, until the time of copulation.

SPERMIDUCAL PORES. Openings of the vas deferens.

TANYLOBIC PROSTOMIUM. Type in which the peristomium is completely divided, the folds reaching intersegmental groove 1/2, cf. fig. 2, tan.

TUBERCULA PUBERTATIS (ridges of puberty). "A series of 2 or 3 small swellings on successive or alternate segments, or a ridge reaching 3 or 4 or 5 segments. Their location is within the limits of the clitellum but they are sometimes absent (Eaton).

SYMBOLS; Used in descriptions and in keys:
5/6 reference is to the intersegmental groove between the segments indicated.
26-32 means the segments from 26 to 32, inclusive.
25, 26-29, 30 means that the structure begins on 25 or 26 and extends to 29 or 30, recognizing a range of variation.
31, 33, 35 (or 31:33:35) means on alternate segments as designated. If the structure extended from 31 to 35, it would be written 31-35.

5. Summary

1. Seventeen species of earthworms are reported from Arkansas, distributed among 9 genera. Six are regarded as native, 8 are introduced from Europe, and 3 are introductions from Asia.

2. Two types of keys to the species are given.

6. Literature Cited.

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1915 Smith, F. Two new varieties of earthworms with a key to described species in Illinois. Bull. Ill. St. Lab. Nat. Hist. 10:8:551-559

1917 North American Earthworms of the Family Lumbricidae in the Collections of the United States National Museum. Proc. U. S. Nat. Mus., 52:157-182

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7. Explanation of Plate.

Fig. 1. Diagram of anterior end of *Lumbricus*. Somites are numbered, 1-16, and structures used in keys indicated.

d.p. dorsal pore
i.g. intersegmental groove.
m. mouth
o. opening of oviduct
per. peristomium
pro. prostomium
s. septum
s.s. sperm sac
st. spermatheca
v.d. opening of vas deferens or spermiducal pore

Testes are represented in 10 and 11, and the ovary in 13, but they are not labeled.

Fig. 2. Anterior end, showing types of prostomium. After Olson.

epi. epilobic
tan. tanylobic

Fig. 3. Diagram of setal arrangements. After Stephenson.

a, *b*, *c* setae lettered from mid-ventral line
z, *y*, *x* setae lettered from mid-dorsal line
lum. lumbricine
pch. perichaetine

Fig. 4. Diagram of types of clitellum.

cing. cingulum
sad. saddle-shapped

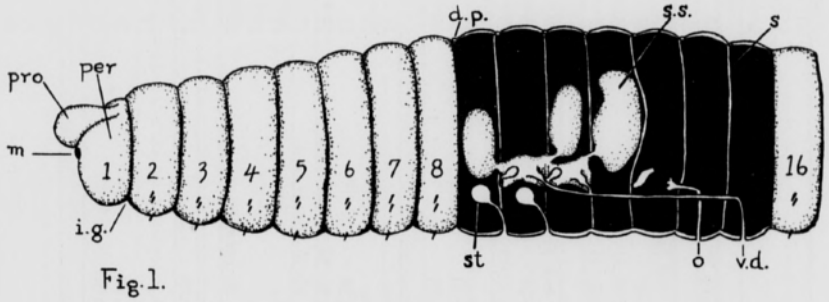

Fig. 1.

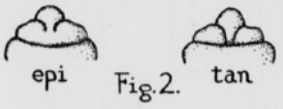

Fig. 2.

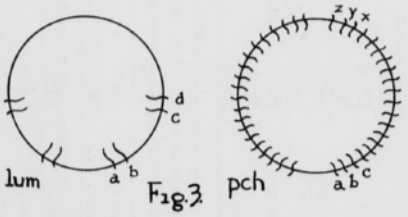

Fig. 3

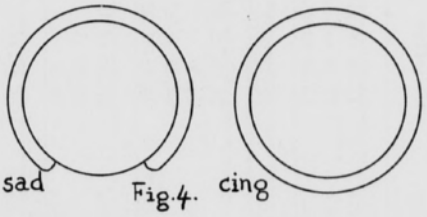

Fig. 4.

Tabular Key to Earthworms

Name	Clitellum	Tubercula pubertatis	Spermiducal pores	Spermathecal pores	Sperm sacs	Setae	First Dorsal Pore
Diplocardia							
D. singularis	13-18 cingulum		19	6/7,7/8,8/9	9,12	wide	7/8
D. communis	13-18 saddle		19	6/7,7/8,8/9	9,12	wide	7/8
D. riparia	13-18 saddle		19	7/8,8/9	9,12	wide	10/11
Eisenilla							
E. tetraedra	22,23-26,27	23-25,26	13	9/10,10/11 (dorsal)	9-12	close	4/5
Eisenia							
E. veneta	24,25,26,27,32,33	30 and 31	15	9/10,10/11 (dorsal)	9,11,12	wide	5/6
E. lönnbergi	24-30	26-29	15	8/9,9/10,10/11 (dorsal)	9,11,12	close	7/8
E. foetida	24,25,26-32	28-30,31	15	9/10,10/11 (dorsal)	9-12	close	4/5
E. rosea	24,25-32,33	29-30,31	15	9/10,10/11 (dorsal)	9-12	close	4/5
Allolobophora							
A. caliginosa	27,28-34,35	31 and 33	15	9/10,10/11	9-12	close	9/10 usually
A. longa	27,28-35	32-34	15	9/10,10/11	9-12	close	12/13
A. chlorotica	29-37	31,33,35	15	8/9-10/11	9-12	close	4/5
Dendrobaena							
D. subrubicunda	25,26-31,32	28-30	15	9/10,10/11	9,11,12	wide	5/6
D. octaedra	27,28,29-33,34	31-33	15	9/10-11/12	9,11,12	wide	4/5
Bimastos							
B. palustris	23-28	none	15	none	11 and 12	close	5/6
B. gieseleri	22-29	none	15	none	11 and 12	close	5/6
B. tumidus	22-29	27,28	15	none	11 and 12	close	5/6
B. parvus	24-30	25,26-29,30 indefinite	15	none	11 and 12	close	5/6
B. beddardi	24,25-31,32	24,25-30 indefinite	15	none	11 and 12	close	5/6
B. longicinctus	23-32 or 24-33	none	15	none	11 and 12	close	5/6
B. zeteki	27-37	none	15	none	11 and 12	close	5/6
B. tenuis	26-31	29,30 indefinite	15	none	11 and 12	wide	5/6
Octolasium							
O. lacteum	30-35	31-34	15	9/10,10/11	9-12	wide	8/9,9/10 or 10/11
Lumbricus							
L. rubellus	27-32	28-31	15	9/10 and 10/11	9,11, and 12	close	7/8
L. castaneus	28-33	29-32	15	9/10 and 10/11	9,11, and 12	close	6/7
L. terrestris	31,32-37	33-36	15	9/10 and 10/11	9,11, and 12	close	7/8
Pheretima							
P. californica	14-16		18	7/8,8/9	11 and 12	all	11/12
P. hupeiensis	14-16		18	7,8,9	11 and 12	peri-	11/12-12/13
P. diffringes	14-16 (all cingula)		18	5/6-8/9	11 and 12	chaet.	11/12

--Continued

Tabular Key to Earthworms (Continued)

Name	Number of somites	Length in cm.	Color antero-dorsal	Notes
Diplocardia				
D. singularis	90-120	18-30	flesh	Garden soil, leaves, hillsides
D. communis	125-160	18-30	pale flesh	Garden soil
D. riparia	135-160	20-27	dark brown	Garden soil
Eisenilla				
E. tetraedra	80-100	4-6	brown	Water-soaked banks of streams, ponds, etc.
Eisenia				
E. veneta	80-120	3.5-5		Stream banks
E. lönnbergi	138	9.6	brownish-violet	
E. foetida	75-125	5-15	brown and buff bands	Manure and compost heaps, decaying logs, etc.
E. rosea	120-150	3-8	pale red	
Allolobophora				
A. caliginosa	100-250	5-20	rose or brown red	Garden and woodland soil, river-bottom land.
A. longa	160-200	12-16		
A. chlorotica	80-125	5-7	greenish	
Dendrobaena				
D. subrubicunda	60-125	5-8	red	Wet soil with sewage contamination
D. octaedra	80-95	2.5-4	violet-brown	
Bimastos				
B. palustris	80-100	7.5	pale red	Wet banks of streams and ponds
B. gieseleri	100-110	4-7	brown-red	Decayed leaves, rotten logs, etc.
B. tumidus	40-60	2-5	reddish-brown	Decayed leaves
B. parvus	85-111	2.5-4	brown-red	
B. beddardi	70-100	2-6	reddish-brown	Wet areas, decaying logs, etc.
B. longicinctus	100-130	7-10	rose-red	Lawns and woodlands
B. zeteki	100-140	10-14	purplish-brown	Decaying logs, leaf mold
B. tenuis	90-110	4-8	rose-red	Decayed leaf mold and logs
Octolasium				
O. lacteum	100-170	5-16	pale pink	Under logs, leaf mold, etc.
Lumbricus				
L. rubellus	90-150	7-15	reddish brown	Debris along shores
L. castaneus	90	3-5	brown-violet	
L. terrestris	100-175	10-30	brown-violet	Lawn and garden soil
Pheretima				
P. californica	105-112	5-12.5	brownish	
P. hupeiensis	119-132	4.5-12	dark cream	Garden soil, etc.
P. diffringes	90-113	4.5-17	brownish	Damp soil along stream

THE ORAL AND BRANCHIAL MOVEMENTS OF DEVELOPING ANURAN EMBRYOS AND LARVAE

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INTRODUCTION

During the last part of the nineteenth century, studies on the development of behavior in amphibians were discontinued. These studies were re-established by Coghill, who worked extensively with *Ambystoma*. (See his 1929 review for a summary of this work.) The researches of Coghill were confined primarily to the swimming, walking and feeding mechanisms in *Ambystoma*.

In *Ambystoma*, there is a progressive antero-posterior recruitment of the axial musculature in the development of the swimming responses. As mouth, gill and limb musculature develops, it too is recruited to take part in the total reaction of the animal. The local reflexes are individuated from the total pattern only after this generalized activity can be elicited.

Coghill's studies attracted the attention of many investigators and led to an ever increasing amount of literature on behavior problems. See Hooker (1936) and Carmichael (1946) for reviews of the literature.

Among the workers directing their efforts toward the solution of behavior problems was Youngstrom (1938), who studied the development of swimming movements, spontaneous eye movements, and the onset of local reflexes in the fore and hind limbs of Anurans.

In Anurans, a previously uninvestigated behavior pattern is established in late embryonic life. This is the development of mouth movements and the establishment of a regular respiratory rhythm. It is with the onset of local mouth reflexes and the establishment of a rhythmic ventilatory rate that this paper concerns itself.

The only reference to the respiratory movement reflex is that of Youngstrom (1938), who notes that in *Pseudacris triseriata* "the gill rhythm is established by the 6 millimeter stage".

Anurans lend themselves well to studies of this nature because of their accessibility and their size, which is small enough to require little laboratory space, yet large enough to permit convenient manipulation for study. As the embryos are nourished by their own yolk, the constancy of a food supply presents no problem.

MATERIALS AND METHODS

Animals observed in this study were embryos of *Rana pipiens*, *Pseudacris nigrita triseriata* and *Bufo americanus*. Larval forms of *Rana pipiens* only were observed.

Several groups of *Rana* eggs were used. The first group of eggs was obtained by induced ovulation and artificial fertilization using Rugh's method (1934). Later, additional embryos of *Rana* plus those of *Pseudacris* were secured from ponds in the Iowa City area. *Bufo* specimens were supplied by Mr. Chih Ye Chang.

Groups of approximately 30 eggs each were placed in finger bowls about one-half full of water. The animals were allowed to develop at room temperature.

Upon attaining a morphological stage of development suitable for this study, each embryo was transferred to a dish lined with paraffin containing 2-3 cc. of water, just enough to cover the specimen. The paraffin contained a shallow groove which helped to hold the animal in place. The embryo was then placed on its dorsal surface, with the ventral surface exposed. With the animal in this position, identification of its morphological stage of development was made possible, and the responses to tactile stimulation of the oral region were readily observed.

The animals were stimulated with a human hair sealed into a glass tube by paraffin. Because of the variability of the responses to oral stimulation, the side of the hair was drawn over the oral region of the animal several times in order to elicit the most advanced response of which the embryo was capable.

The embryo was then transferred to a glass caster dish containing about 10 cc. of water through which air had been bubbling for several hours. Following the transfer, the animal was left undisturbed for several minutes. The branchial region was then observed for evidences of respiratory movements. When these movements were present, they were timed to two-tenths of a second with the use of a Meylan stop watch. The time required for twenty respiratory movements in a quiescent embryo was recorded, and the number of respiratory movements per minute was calculated.

The temperature of the water in which the animals were placed for observation of their respiratory rhythms varied between 23° - 27° C. during the course of these experiments.

Serial sections of some animals in representative stages were prepared. Staining of these sections was done with Delafield's haemotoxylin and eosin.

Morphological stages

The morphological staging followed in this experiment was that propounded by Shumway (1940) for *Rana pipiens* embryos. Stage 24 was subdivided into quarter intervals (24 1/4, 24 1/2 and 24 3/4) according to the extent of closure of the operculum. The method used for stage identification of sectioned material was that of Shumway (1942) for *Rana pipiens*. The staging of larval forms of *Rana pipiens* followed that of Taylor and Kollros (1946).

Behavior stages

The stages of response to tactile stimulation are primarily adapted from those described by Coghill (1929) for *Ambystoma*. No attempt was made to differentiate between the S response and early and late swimmers. All were classified as giving the S type response.

Stage C - The coil stage. The embryo forms a half-circle with its body in a direction toward the side of stimulation, as in the early flexure stage.

Stage RC - The reversed coil stage. The embryo forms a half-circle as in the preceding stage, but then reverses the half-circle.

Stage S - The repeated reversed coil stage. The embryo forms several rapid reversed coils in succession, giving the appearance of an S shape to the body. Included in this stage are the early and late swimmers.

Stage G - The external gills are depressed and the mouth of the embryo twitches.

RESULTS

Onset of mouth movements

Embryos of *Rana, Bufo* and *Pseudacris* were tested for responses to tactile stimulation of the oral region. The results are given in Tables I, II and III. These tables indicate that, for all forms studied, movements of the mouth are established in morphological stage 23.

Establishment of a regular respiratory rate

Respiration by an internal gill system is instituted only after the embryo has established mouth movements. The first indication of respiratory movements in the *Rana pipiens* embryo occurs in late stage 23. These movements consist of spasmodic gulps and are evidenced particularly after prolonged swimming. These movements are highly irregular in rate and were observed in only a few animals. In animals exhibiting these spasmodic movements, the number of gulps between prolonged pauses ranged from 3 to 14.

With the beginnings of opercular closure on the right side of the embryo (stage 24 1/4), the animal initiates rhythmic respiratory movements.

The influence of temperature on the rate of respiratory movements was determined in a series of timings of *Rana* embryos in stages 24 and 25. The results are presented in Graph I. With but three exceptions in twenty-six cases, the higher temperature was accompanied by the higher respiratory rate. The Q_{10} or respiratory movement activity for *Rana* ranged between 0.9 and 1.5.

TABLE I

The number of *Rana pipiens* embryos showing different types of responses to tactile stimulation of the oral region

Behavioral Stage / Morph. Stage	No Response	C	RC	S	G
20	2	1	3	7	
21	1		3	9	
22			1	11	
23				5	29
24					35

TABLE II

The number of *Bufo americanus* embryos showing different types of responses to tactile stimulation of the oral region

Behavioral Stage / Morph. Stage	No Response	C	RC	S	G
20			3	9	
21			3	12	
22				11	1
23				1	22
24					31

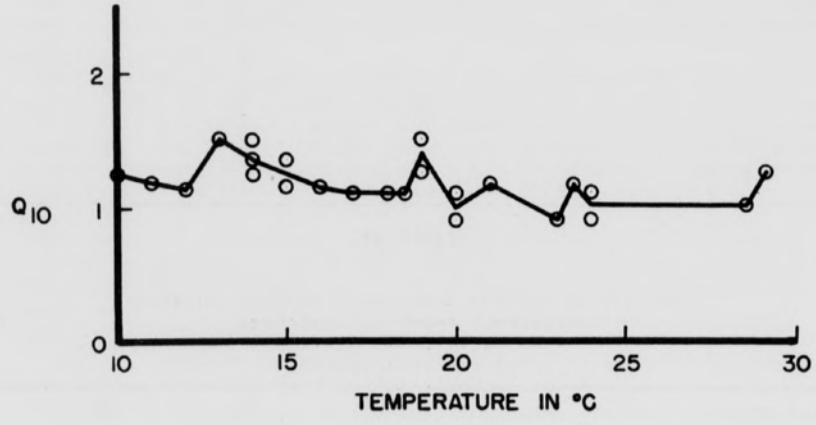
TABLE III

The number of *Pseudacris nigrita triseriata* embryos showing different types of responses to tactile stimregion

Behavioral Stage / Morph. Stage	No Response	C	RC	S	G
20				14	
21				11	
22				16	
23				2	20
24					29

GRAPH I

THE EFFECT OF TEMPERATURE ON THE RATE OF RESPIRATORY MOVEMENTS OF RANA IN MORPHOLOGICAL STAGES 24 TO 25.



The rates of breathing movements for *Rana* in morphological stages 24 1/4, 24 1/2, 24 3/4 and 25, in the 23° - 27° C. temperature range, are presented in Graph 2. This graph shows that there is a progressively faster rate of respiratory movements in stages 24 1/4 to 24 3/4. The number of ventilatory movements per minute decreases in stage 25. The differences between successive intervals are all significant. (See Table IV for significance of differences.)

Of the various forms studied, *Bufo* is the first to establish respiratory rhythm, the onset taking place usually in stage 23. Regularity of breathing movements does not appear in *Pseudacris* until late stage 25. Graphs 3 and 4 give the number of breathing movements per minute for *Bufo* and *Pseudacris*. From Graph 3, the respiratory movement rate for *Bufo* appears to increase with growth from stages 23 to 25, although the only significant difference is that between stages 24 1/2 and 24 3/4. (See Table IV for significant differences.)

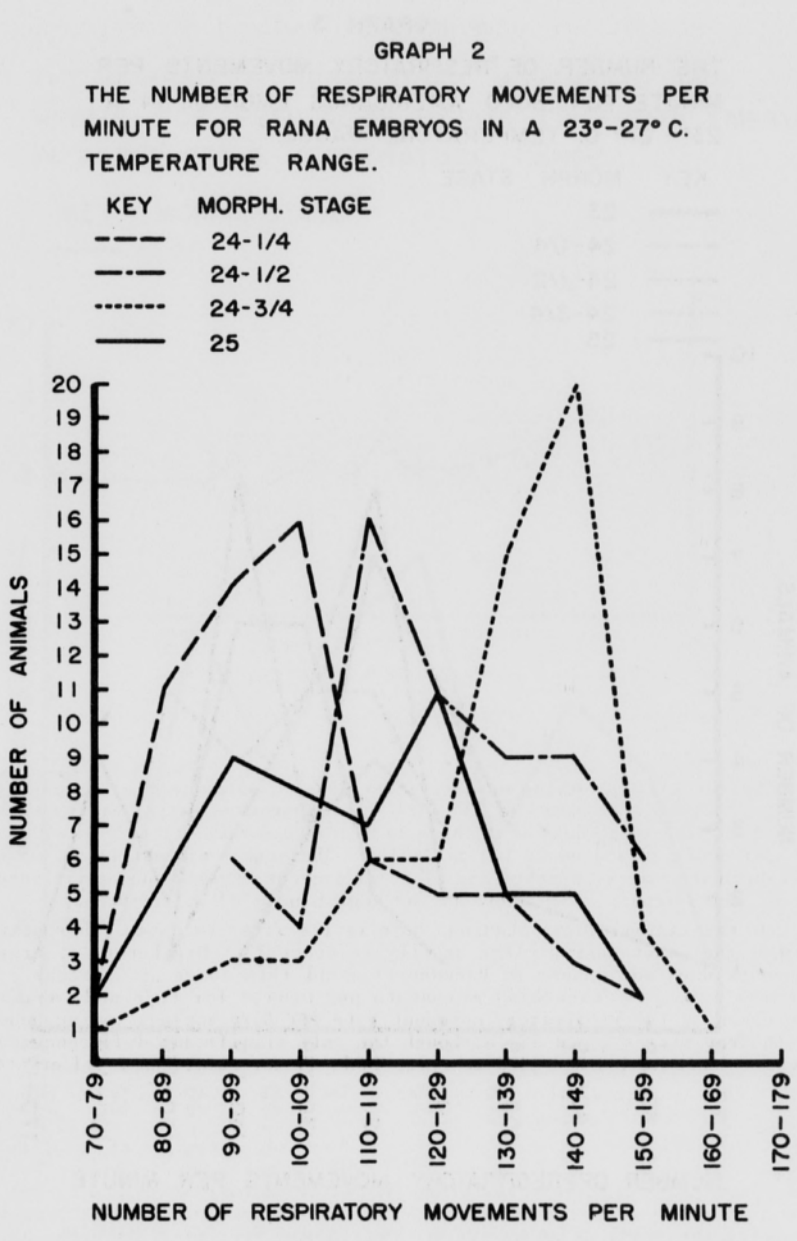
Graph 4 indicates that the number of ventilatory movements per minute for *Pseudacris* ranges between 70 and 169.

A comparison of the average rates of breathing movements of *Rana*, *Bufo* and *Pseudacris* and the significance of the differences is presented in Table IV. *Bufo*, besides initiating respiratory rhythm at an earlier morphological stage than *Rana* or *Pseudacris*, also has significantly faster rates of ventilatory movements than *Rana* in stages 24 1/4 and 25 and *Pseudacris* in stage 25. The difference between rates of *Rana* and *Pseudacris* in stage 25 is not significant.

Rana larvae (stages I to IV), as seen in Graph 5, show a range of 108 to 121 respiratory movements per minute in these stages.

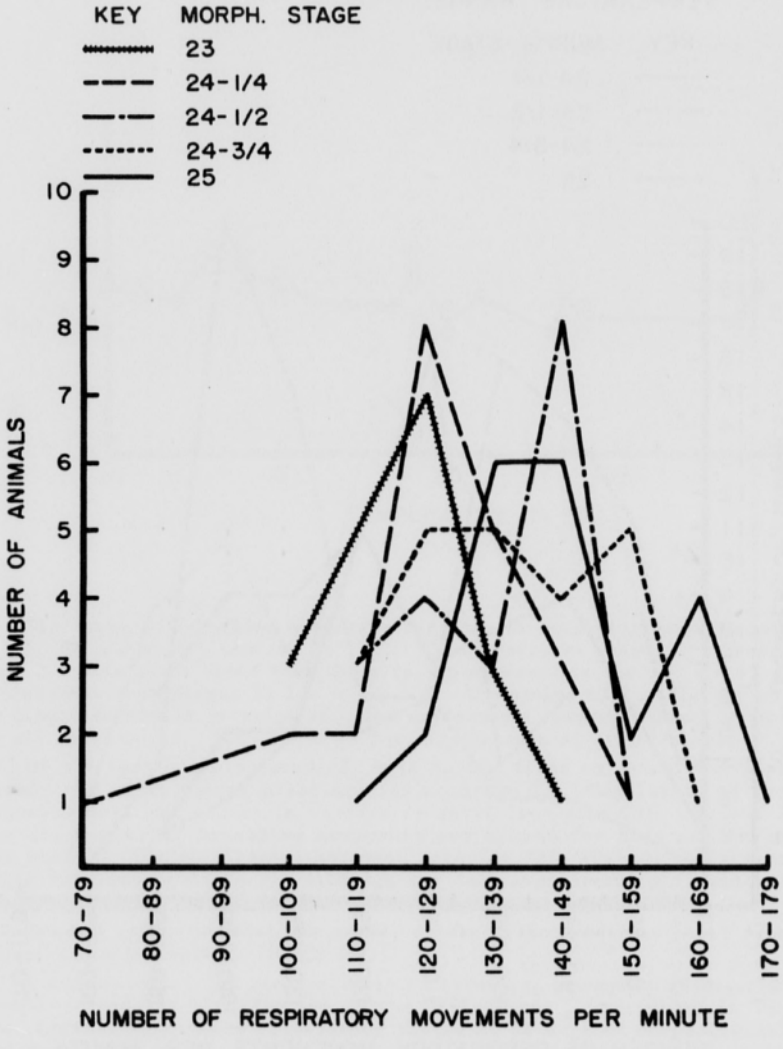
GRAPH 2

THE NUMBER OF RESPIRATORY MOVEMENTS PER MINUTE FOR RANA EMBRYOS IN A 23°-27° C. TEMPERATURE RANGE.



GRAPH 3

THE NUMBER OF RESPIRATORY MOVEMENTS PER MINUTE FOR BUFO AMERICANUS EMBRYOS IN A 23° - 27° C. TEMPERATURE RANGE.



GRAPH 4

THE NUMBER OF RESPIRATORY MOVEMENTS PER MINUTE FOR PSEUDACRIS NIGRITA TRISERIATA EMBRYOS IN A 23°–27° C. TEMPERATURE RANGE.

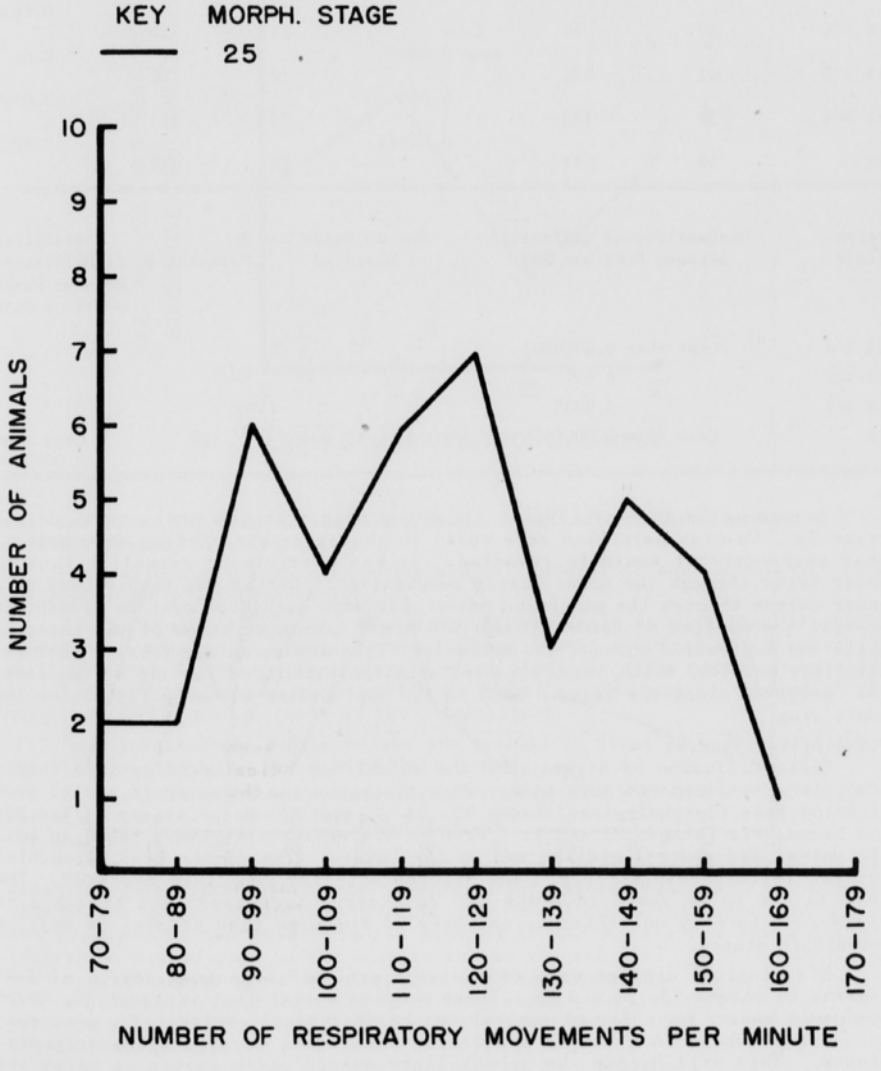


TABLE IV

The average number of breathing movements per minute for *Rana*, *Bufo* and *Pseudacris* in the 23° - 27° C. temperature range and the significance of the differences of these means

Morph. Stage	No. of Animals Observed	*Rana*	Probability	No. of Animals Observed	*Bufo*	Probability
23				19	126	
						0.6456
24 1/4	64	99	Less	24	128	
			than 0.006			0.66
24 1/2	61	122		19	130	
			0.026			0.0086
24 3/4	59	133		23	141	
			0.00034			0.8258
25	54	111		22	142	

Morph. Stage	Probability of difference between *Rana* and *Bufo*	No. of Animals Observed	*Pseudacris*	Probability of Difference Between *Pseudacris* & *Bufo*
24 1/4	Less than 0.0000006			
24 1/2	0.097			
24 3/4	0.0332			
25	Less than 0.0000006	40	113	Less than 0.0000006

According to Shumway (1947), the nares open into the oral cavity during stage 23. Carmine particles were added to the water surrounding an embryo so that water current would be revealed. It was possible to establish that no water exits through the nares during respiration. During the inspiratory act, water enters through the mouth and nares, but some mechanism must be present to prevent the outflow of water through the nares during aeration of the internal gills and expiration through the spiracle. This mechanism may involve the premaxillary muscles, which, when elevated with the raising of the tip of the lower jaw, serve to close the nares. Such is the explanation of Gaupp (1896) for the adult frog.

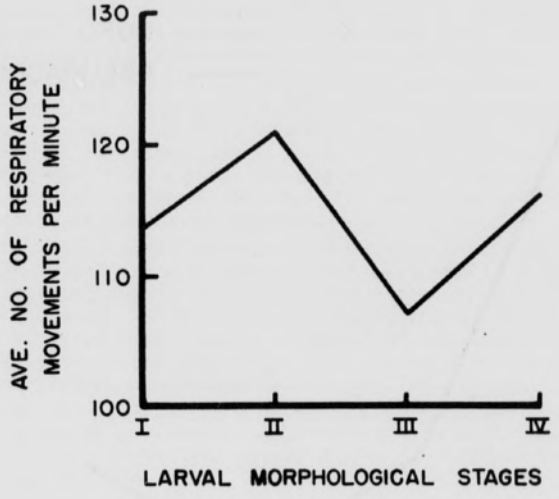
Histological studies

Since diffusion of oxygen into the animal may be affected by skin thickness, skin measurements were made. Skin thickness was measured in serial sections of *Rana* (morphological stages 23, 24, 25 and I), *Bufo* (stages 24 and 25) and *Pseudacris* (stages 23 and I). Five or six measurements were taken in both the dorsal and ventral midline and in the lateral area of the head, branchial and gut regions respectively. The figures obtained were then averaged. The results are to be found in Graph 6. This graph indicates that the skin of *Pseudacris* is only one-third to one-half as thick as that of *Rana* or *Bufo* in comparable stages.

Histological studies were made of the oral and branchial region of *Rana pipiens* in stages 23, 24 and 25. These studies reveal that in stage 23, three premuscle masses have formed ventral to the pharyngeal cavity. The most conspicuous of these is a thick, apparently interwoven mass of transverse myoblasts. This will become the submaxillary muscle which serves to raise the floor of the buccal cavity. Fibrillae may be seen and the nuclei of the fibers exhibit various stages of mitoses.

GRAPH 5

THE AVERAGE NUMBER OF RESPIRATORY MOVEMENTS PER MINUTE FOR RANA PIPIENS LARVAE AT 25° C. (THE AVERAGE GIVEN FOR EACH STAGE IS BASED ON THE VENTILATORY RATE OF TEN ANIMALS IN THAT STAGE.)



Dorsal to the submaxillary muscle, two longitudinal muscle masses are visible with ovoid, dividing nuclei.

Several precartilage masses are present lateral to and immediately under the buccal and pharyngeal cavity.

In the stage 24 embryos, the submaxillary muscle is much thinner and the fibers are arranged in parallel rows. These fibers manifest striations. The still dividing nuclei are beginning to align along the sides of the fibers. The attachment of the submaxillary muscle to Meckel's cartilage is evident at this stage, as is the median raphe of the submaxillary.

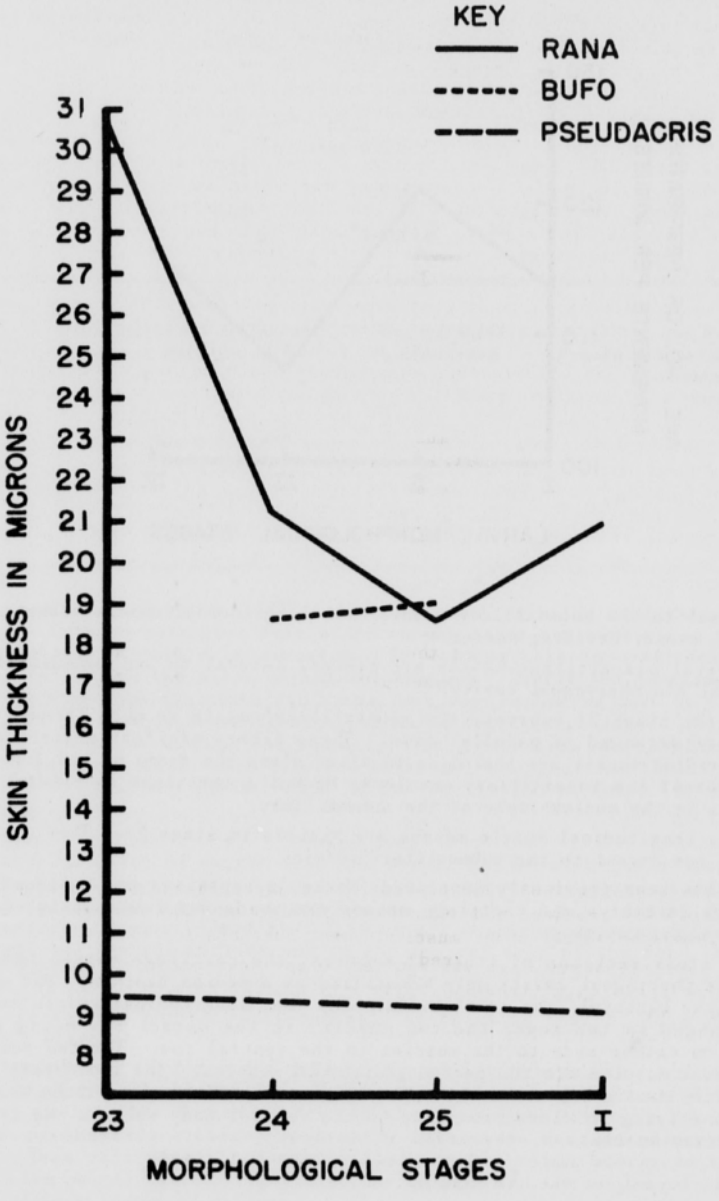
Four longitudinal muscle masses are visible in stage 24. They appear in a parallel row dorsal to the submaxillary muscle.

As has been previously mentioned, Meckel's cartilage may be identified in the stage 24 embryo and cartilage masses are evidenced immediately ventral to the pharyngeal cavity.

In cross sections of stage 25 embryos, the cartilage masses immediately under the pharyngeal cavity were identified as a median basihyal, and on either side of the basihyal, the ceratohyals. The four longitudinal muscle masses are now arranged in two rows, the two muscles in the dorsal row being slightly lateral on either side to the muscles in the ventral row. The two ventral and more medial muscles are the paired geniohyoid muscles. The two dorsal and lateral muscle masses represent the split hyoglossus. Ventral to these four muscle masses and lying in close proximity to the ventral body wall is the transverse submaxillary muscle.

GRAPH 6

THE AVERAGE THICKNESS OF THE SKIN FOR RANA, BUFO AND PSEUDACRIS.



DISCUSSION

This problem, which is an amplification of the work of Coghill, reveals that embryos of *Rana, Bufo* and *Pseudacris* show a sequence of developing behavior patterns for the oral region similar to that found by Coghill in *Ambystoma.* However, Coghill also demonstrated that *Ambystoma*, a carnivorous feeder, showed a feeding or snapping reaction. *Rana, Bufo* and *Pseudacris*, herbivorous or omnivorous feeders as larvae, do not show this sort of response until after metamorphosis.

In all forms included in this study, the onset of a local mouth response to tactile stimulation occurs in stage 23. It is at this stage that cross sections of *Rana* reveal the presence of fibrillae in the myoblasts of the buccal region. Hooker (1911) noted that in the normal frog embryo, fibrillae must be present for contraction of skelatal muscle to take place.

Water is allowed entry into the buccal cavity through the mouth and nares only when the mouth is opened. Some mechanism, perhaps the premaxillary muscles, causes occlusion of the nares when the mouth is closed. When shut, the mouth and nares, in conjunction with the floor of the buccal cavity, appear to function somewhat like a pump, forcing water into the internal gill chamber. Therefore, respiration by an internal gill mechanism does not take place until after the mouth is capable of movement.

Bufo, in most cases, initiates regular respiratory movements in late stage 23. In *Rana*, ventilatory rhythm is first evidenced in early stage 24 embryos, while the onset of regular breathing movements is delayed in *Pseudacris* embryos until late stage 25. Therefore, spontaneous mouth movements occur at a later developmental stage than do mouth movements in response to tactile stimulation. Hooker (1911) similarly found that contractility in response to stimulation precedes spontaneous contractility.

The fact that *Pseudacris* does not initiate rhythmic respiratory movements until late stage 25 is perhaps explainable by its small size and thin skin. It is possible that a sufficient oxygen supply is obtained in *Pseudacris* by diffusion through its body wall. Thus, the need for a special respiratory mechanism may not arise in *Pseudacris* until a later morphological stage than in the larger and thicker skinned *Rana* and *Bufo* embryos.

The size of the animal is a factor because of the relationship of surface area to mass. When the animal increases in size, the surface increases only as the square, the mass as the cube. There is, then, a relative decrease in the area through which diffusion may take place.

In *Rana*, which shows a significant increase in breathing movement rate up to stage 25, the surface-mass relationship may also be a factor, for the skin is thicker in stage 23 than in any following stage observed.

Very little difference is evidenced in the respiratory movement rate of *Rana* in the change from embryonic to larval life.

SUMMARY

1. Egg clutches of *Rana pipiens, Bufo americanus* and *Pseudacris nigrita triseriata* were procured and allowed to develop at room temperature until attaining a morphological stage of development suitable for this study.

2. Tactile stimulation was applied to the oral region of these embryos. A sequence of developing behavior patterns, similar to that found by Coghill in *Ambystoma*, was demonstrated for all forms studied. In almost every case, the onset of a local mouth reflex was established in stage 23.

3. Histological studies of *Rana* reveal the presence of fibrillae in the myoblasts of the oral and branchial region in stage 23. Cross-striations are present at stage 24.

4. In every case, the onset of regular respiratory movements, which involves spontaneous mouth movements, was delayed until after the establishment of a mouth response to tactile stimulation.

5. *Bufo*, the largest form studied, exhibits rhythmic ventilatory movements in late stage 23 with but few exceptions. Regular breathing movements are not

seen in *Rana* until early stage 24, and do not occur in *Pseudacris* until late stage 25. The comparatively late establishment of regular breathing movements in *Pseudacris* may be attributed to its smaller size and thinner skin.

6. In *Rana* embryos, with the exception of stage 25, an increase in age is accompanied by a significant increase in the average number of respiratory movements per minute. In *Bufo*, the average ventilatory rate appears to increase with age, but the differences are not significant.

7. *Bufo*, the first to institute ventilatory rhythm, has a significantly higher average rate of respiratory movements per minute than does *Rana* or *Pseudacris* in stage 25. There is no significant difference in the average ventilatory movement rate per minute between *Rana* and *Pseudacris* in stage 25.

8. No marked difference is evidenced in the respiratory movement rate of *Rana* in the change from embryonic to larval life.

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LIMNOLOGICAL STUDIES IN ARKANSAS*

1. Physico-chemical and Net Plankton Studies of Lake Fort Smith in Its Fourth Year of Impoundment

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University of Arkansas

This limnological investigation gives information on the physico-chemical features, kinds and numbers of net plankters and seasonal distribution of the plankton of a lake in the early years of its impoundment. Little is known concerning the development of plankton populations in an artificial lake over a period of years. A second study, now in progress, is concerned with net and nannoplankton studies of Lake Fort Smith in its fourteenth and fifteenth years. This lake was selected for this study because it was built primarily for a water supply and, up to the present time, has not been drained or fertilized and, with the exception of occasional restocking of fish, has not been purposely altered since the lake was filled to its capacity in May 1936.

Grateful acknowledgments are made to Professor Paul S. Welch of the University of Michigan for reading the manuscript and for his helpful suggestions; to Mr. H. S. Peck, of the City of Fort Smith Water Department, for the use of a boat and other assistance; to Dr. Virgil Sleight, Department of Geology, Miami University, for help in determining the nature of the total suspended matter and obtaining hydrographic data; to Dr. Perry Max Johnston, Mrs. Barbara Carson and Mr. Andrew Hulsey for aid in computing morphometric data; and to the Research Committee of the College of Arts and Sciences, University of Arkansas and Dean Virgil L. Jones for continued interest and grants which made this work possible.

METHODS AND EQUIPMENT

Although occasional trips for plankton collections and temperature determinations were made during the first half of 1938, regular trips were begun in June of 1938 and continued at intervals of from one to two weeks throughout 1939. Beginning in December of 1938 chemical studies were included. The data of this paper are essentially for a year beginning in December, 1938 and extending on through all of 1939. Records taken during 1938 are referred to as needed.

Temperatures were determined with a Taylor maximum and minimum thermometer until the early fall of 1938 when an H-B Instrument Company "Deep Sea" reversing thermometer was substituted. Temperatures were always taken at each meter from the surface to the bottom. Transparency was estimated by means of a standard Secchi's disc and turbidity by the platinum wire method.

The chemical determinations of dissolved oxygen, free carbon dioxide and alkalinity were made in accordance with the methods described in the Standard Methods of Water Analyses (1936). Hydrogen-ion concentration determinations were made with a Hellige disc colorimeter.

The water samples for chemical analyses and plankton were obtained with a modified Kemmerer sampler and a rope calibrated in meters. For the plankton samples 20 liters of water were concentrated through a number 25 silk bolting-cloth plankton net. The settling suspended matter was determined by pouring each plankton sample into a 100 cc. graduated centrifuge tube and allowing the solids present to settle. This same sample was later used to determine the number of organisms per liter. Counting of the plankton was done in a counting chamber, all of the organisms in two different cubic centimeters being counted and the results expressed in terms of liter numbers. This method of counting was used by Raymond (1937).

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DESCRIPTION OF THE LAKE

Lake Fort Smith is in northwestern Arkansas, twenty-five miles northeast of the city of Fort Smith. The area is in the Humid Subtropical climatic zone, near the northern border of the latter. It is located several hundred miles farther north than the lakes in Texas and Louisiana which have been investigated by Harris and Silvey (1940), Cheatum, Longnecker, and Metler (1942) and Moore (1950).

The watershed for Lake Fort Smith lies on the southern side of the Boston Mountains, and is hemmed in by the latter on all sides but towards the south. The surrounding mountains rise from 1000 to 1500 feet above the valley, being the lowest to the east. The watershed generally trends from northeast to southwest, and is 65 square miles in extent.

Lake Fort Smith is a reservoir lake formed by damming a mountain valley just above the village of Mountainburg, Arkansas. The long axis of the lower end of the lake lies in a roughly north-south direction, with the dam at the southern end while the long axis of the upper end is in an east-west direction. The lake thus formed by impounding the water of Clear Creek (Jones Fork of Frog Bayou on the topographical map) covers 525.5 acres. The lake is surrounded by steep, wooded hills except at the northeast end where Clear Creek enters and the southern end where a dam 2,000 feet long and 90 feet high forms its boundary. The dam closing was completed in February, 1936, and the lake was filled to capacity by May of the same year. The lake is about 800 feet above sea level.

The slope of the basin is generally steep, except at the northern end. The bottom deposits of the deeper portions of the lake were those of a drowned mountain valley, namely, rocks of limestone, sandstone, and shale, with sand and gravel in the old stream bed, all with a thin superficial cover of clay. Practically no aquatic vegetation had appeared along these steeper slopes of the basin. At the northern end of the lake the water is shallow and, at low water level, expanses of several acres of the bottom became exposed, revealing tree stumps, dead bushes and some evidence of one time cultivation. In the fall of 1939 the old rows of corn stalks were still visible in the former field. A very small amount of *Typha, Sagittaria, Chara* and *Dianthera* was found at the northern end.

Clear Creek becomes dry, except for an occasional waterhole, during the summer. The channel where it enters the lake is a long meandering Bayou, with the transitional area between the stream and lake covering several acres. In 1939 this area was similar to bottom lands subject to periodic overflow.

MORPHOMETRY

Direction of axis, upper end	east-west
Direction of axis, lower end	north-south
Maximum length	13,800 feet
Maximum effective length, upper end	7,900 feet
Maximum effective length, lower end	6,850 feet
Maximum width	2,600 feet
Mean width	1,660 feet
Maximum depth	72 feet
Mean depth	22.94 feet
Shore line	38,800 feet
Area	22,896,000 square feet
Shore development	2.29
Volume	525,598,000 cubic feet
Volume development	0.95

PHYSICAL

Temperature

Temperature studies for the year 1939 showed that Lake Fort Smith had a stratification period and one of nonstratification. The water during the latter period was near enough to being homothermal to allow circulation. According to Whipple's classification of lakes, Lake Fort Smith during 1939 would be regarded as a tropical lake of the second order, with bottom temperatures always above 4.0°C. The lowest surface temperature recorded during the year 1939 was 5.2°C.,

while the lowest bottom temperature was 4.9°C. During the winter of 1940 the lake was covered with a thin coating of ice which would classify it as a temperate lake for that year. Table I summarizes the temperature conditions for the period from December 28, 1938 through December 10, 1939 and gives the position of the thermocline during stratification.

In 1938 nonstratified water was first found on November 20 when the surface water was 12.8°C., and water at the bottom was 11.8°C. In 1939 circulation began on November 12, when the surface water was 12.8°C. while the water at the bottom was 13.0°C. In a few instances the bottom temperature at the time of nonstratification was slightly warmer than the water at a meter or two above; the greatest difference at this time was 0.4°C.

TABLE I. Summary of Thermal Conditions in Lake Fort Smith from December 28, 1938 through December 10, 1939.

	Epilimnion		Thermocline			Hypolimnion		
Date	Top (°C.)	Bottom (°C.)	Meter below Epilimnion (°C.)	Meter above Hypolimnion (°C.)	Location (meters)	Top (°C.)	Lowest (°C.)	Bottom (°C.)
12/28	5.2		No stratification				5.2	5.3
1/8	6.8		No stratification				5.8	5.8
1/22	5.9		No stratification				5.6	5.9
2/5	5.4		No stratification				4.9	4.9
2/12	6.2		No stratification				5.2	5.4
3/7	8.1		No stratification				6.4	6.4
3/14	10.0		No stratification				7.2	7.2
3/19	10.4		No stratification				7.6	7.6
4/2	18.0	15.0	13.2	11.6	4-5	10.4	8.2	8.2
4/8	12.2		No stratification				9.0	9.0
4/23	14.2		No stratification				9.8	9.8
5/7	19.2	18.0	15.4	13.4	5-6	12.0	10.6	10.6
5/14	19.0	17.2	14.6	14.6	5	12.4	10.6	10.6
5/23	- -	- -	23.3*	16.0	0-5	14.8	10.4	10.6
6/7	- -	- -	26.4*	16.4	0-5	14.6	10.8	10.8
6/15	27.6	26.2	24.0	15.0	3-6	13.6	10.8	10.8
6/23	29.8	29.6	28.0	17.8	2-6	12.0	11.0	11.0
6/27	28.8	27.8	23.2	18.0	5-6	14.2	11.0	12.2
7/6	29.6	28.6	25.8	17.6	4-6	15.0	10.8	10.8
7/15	31.6	28.6	23.0	13.6	5-9	12.4	10.0	10.0
7/21	30.4	28.4	22.6	14.4	5-7	13.0	11.2	11.2
7/28	29.4	28.4	23.4	15.0	5-7	13.8	11.0	11.4
8/11	28.0	27.0	25.0	13.8	5-8	12.6	11.0	11.0
8/17	27.6	27.0	24.4	13.2	5-9	12.0	11.0	11.0
8/24	27.0	25.8	18.8	13.0	6-8	12.0	11.0	11.0
8/31	27.0	26.8	24.7	14.4	5-7	12.8	10.9	10.9
9/7	27.8	27.6	24.0	13.2	5-8	12.2	11.0	11.0
9/24	24.0	23.6	15.0	15.0	7	12.7	11.2	11.2
10/1	20.6	20.0	19.0	19.0	7	13.0	11.0	11.0
10/15	18.6	18.4	15.9	13.4	8-9	12.0	11.0	11.0
10/29	17.0	17.0	13.6	13.6	10	12.0	11.2	11.4
11/12	12.8		No stratification				12.6	13.0
11/26	10.8		No stratification				10.6	10.8
12/10	10.8		No stratification				9.2	9.6

* Surface temperature

On April 2, 1939 a temporary stratification appeared. On this date the temperature varied 9.8°C. from the surface to the bottom. Permanent stratification began on May 7 with a surface temperature of 19.2°C., and with the bottom temperature of 10.6°C. Temperature records taken in 1940 showed that the lake was stratified by May 12 of that year.

In 5 records secondary thermoclines were found: on April 2 there was a drop of 2.4°C. between the surface water and the water at meter 1; on May 14 there was a 1.4°C. drop between the surface and the first meter; on May 23 there was a 1.0°C. drop between meters 8 and 9; on July 15 and July 21 there was a 1.2°C. drop between meters 2 and 3.

Transparency and Turbidity

The authors are aware of the limitations of the Secchi's disc but feel that it does give some relative measure of the changes in water transparency throughout a year. Table II summarizes the Secchi's disc readings for the year 1939.

The disc readings from March 7 through May 23 varied from 25 to 6.5 cm. This period can be correlated with the heavy late winter and spring rains and the inflow from the surrounding hills. The wind action may have played a small part at this time but, because of the nature of the bottom, this influence was probably small; the bottom was composed of rock and gravel. The correlation between rainfall and transparency was not as evident later in the year as in the spring, which may have been due to the rapid absorption of the rainfall by the extremely dry, vegetation-bearing soil of the watershed in summer and fall. An additional factor may have been that substances accumulated on the hills during the winter were brought down by the rains in large quantities in the spring. The shortest disc reading for Lake Fort Smith was 25 centimeters while the longest was 300 centimeters.

TABLE II. Summary of Secchi's Disc Readings in Centimeters for the Year 1939

Date 1939	Trans-parency	Date 1939	Trans-parency	Date 1939	Trans-parency
Feb. 12	150	June 7	130	Aug. 24	240
Mar. 7	25	June 15	150	Aug. 31	150
Mar. 14	33	June 23	200	Sept. 7	200
Mar. 19	33	June 27	200	Sept. 24	200
Apr. 2	65	July 6	190	Oct. 1	190
Apr. 8	50	July 15	300	Oct. 15	190
Apr. 23	50	July 21	290	Oct. 29	150
May. 7	50	July 28	240	Nov. 12	130
May 14	50	Aug. 11	200	Nov. 26	150
May 23	65	Aug. 17	200	Dec. 10	250

TABLE III. Summary of Precipitation, Secchi's Disc Readings, Settling Suspended Materials and Averaged Organisms per Liter from January 8 through May 7, 1939.

Date 1939	Precipitation in Preceding 7 Days in Inches	Secchi's Disc in cm.	Averaged Settling Suspended Materials in cc. Per 20 Liters	Averaged Organisms Per Liter
Jan. 8	0.00	- -	0.08	181
Jan. 22	0.53	- -	0.08	334
Feb. 5	1.13	150	0.07	192
Feb. 12	0.73	150	0.07	264
Mar. 7	1.56	25	0.36	19
Mar. 14	0.52	33	0.04	4
Mar. 19	0.00	33	0.08	209
Apr. 2	0.11	65	0.05	253
Apr. 8	1.38	50	0.1	137
Apr. 23	2.24	50	0.1	10
May 7	0.00	50	0.08	38

A number of investigators (e.g., Chandler, 1940, 1942) have suggested that turbidity may influence productivity of organisms, especially phytoplankton. In this investigation turbidity readings were not taken during the year 1939 but some information is available about settling suspended materials present in the lake. The materials designated as such are both organic and inorganic in nature, and are what was collected by a number 25 silk bolting cloth plankton net from a 20 liter sample. To determine the amount of settling suspended materials the water sample was introduced into a graduated 100 cc. centrifuge tube and allowed to settle. The readings obtained by this method do not give the volume of the organisms. Table III summarizes the averaged amount of settling suspended materials present in 20 liters of lake water derived from equal samples obtained at the surface, 5, 10 and 15 meters. The average number of organisms per liter of water derived from equal samples from the same levels is also included. The table also gives information concerning the amount of rainfall in the 7 days previous to the time the sample was collected.

Table III shows that there was an accumulation of settling suspended materials after the late winter and spring rains. In summer and fall this correlation is not as evident. A study of suspended materials present in the fall showed it to be mostly flocculent material, while in the spring it was composed of portions of lichens, quartz grains, flat fragments of shale, fragments of limonite and silt.

The best example of the correlation between the presence of settling suspended matter, rainfall and number of organisms was found in March. On February 12 the average reading for suspended matter for the 4 different levels was 0.07 cc. for 20 liters of water. The organisms present averaged 264 per liter. On March 7, after 1.56 inches of rainfall, the average amount of suspended matter was 0.36 cc. for the 20 liter sample, while the average number of organisms had dropped to 19 per liter. On this date a 20 liter sample at meter 5 had 1.1 cc. of suspended matter and 15 organisms per liter. By March 14 the average number of organisms was lower than on March 7; 4 organisms per liter were present, and the average amount of suspended materials was reduced to 0.04 cc. per 20 liters. The latter tends to show that the effects of heavy rainfall may influence the productivity of plankton for a period of a week at this time of the year.

Similar examples can be found on April 8 and 23, but the amount of suspended material is not as high as it was in March. This may have been due to the material having already settled down to the bottom by the time the samples were taken. The dominant organism present during these four months was *Kirchneriella obesa*; it disappeared after the heavy April rains. This organism formed 80 per cent of the total net plankton during this period. Although there are indications that turbidity may have some influence on zooplankton definite conclusions in this investigation are limited to the phytoplankton since they accounted for 93 per cent of the total net plankton at this time.

During the week previous to February 5 there was 1.13 inches of rainfall which should have been sufficient to bring about the same results as it did in March and April. Studies of the rainfall records during this time revealed that this amount of rainfall was fairly evenly distributed over the 7 days instead of being concentrated on one or two days as it had been in March and April. In the February rainfall the water was absorbed by the soil on the hills at the time of the downfall, while in the other instances the heavy short rains carried away large quantities of materials.

Although turbidity readings were not taken during the year 1939, some are available for the years 1940 and 1941, and these are presented together with the Secchi's disc readings. December 20, 1940 the Secchi's disc reading was 150 centimeters and the turbidity reading was 7 parts per million; on February 23, 1941 the disc reading was 40 centimeters and the turbidity reading was 25 ppm.; on October 11, 1941 the disc reading was 200 centimeters and the turbidity was less than 7 ppm.

CHEMICAL

Dissolved Oxygen

The dissolved oxygen content of Lake Fort Smith can be divided into two periods: a period in which the dissolved oxygen has a fairly uniform distribution throughout the depths and another in which the dissolved oxygen is disap-

pearing from the bottom. Table IV summarizes the oxygen distribution at significant meters on some representative dates.

At the time when the lake was circulating a slight reduction in oxygen was noticeable at certain meters, e. g., on January 8 there was a slight reduction at the fifth meter. Other examples of this small reduction are: March 7 at the fifth meter, March 14 and 19 at the surface and April 8 and 23 at the surface and bottom.

Reduction of the dissolved oxygen content in the water near the bottom began May 14. The first oxygen free water was found August 31 at 17 meters; the oxygen free water finally included meter 15 on October 15. Beginning August 17 and continuing through September 7 there was a noticeable reduction of oxygen in the sixth meter.

TABLE IV. Summary of Chemical Factors in Lake Fort Smith of Selected Dates from December 28, 1938 to December 10, 1939.

Date	Depth in Meters	Oxygen ppm.	Free CO_2 ppm.	M. O. Alkalinity ppm.	pH
Dec. 28, 1938	0	7.8	1.5	24.0	6.8
	15	7.3	1.5	24.0	6.8
Jan. 22, 1939	0	10.0	1.0	26.0	6.8
	15	10.0	1.0	26.0	6.8
Feb. 12	0	8.0	1.0	24.0	6.8
	19	8.2	1.0	22.0	6.8
Mar. 7	0	8.3	0.5	23.0	6.6
	18	8.6	1.0	22.0	6.4
Mar. 14	0	9.5	2.0	23.0	6.6
	15	10.1	2.0	22.0	6.6
Apr. 2	0	7.9	0.5	20.0	6.8
	19	7.3	1.5	20.0	6.4
Apr. 8	0	7.1	1.0	17.0	6.8
	18	6.9	1.0	20.0	6.4
Apr. 23	0	8.3	0.5	21.0	6.8
	17.5	8.2	1.0	20.0	6.4
May 14	0	6.5	0.5	20.0	6.7
	19	5.0	1.5	21.0	6.4
June 27	0	6.6	1.5	21.0	6.8
	10	5.7	2.5	20.0	6.4
	18	3.7	2.5	23.0	6.4
Aug. 17	0	7.8	2.0	20.0	6.8
	5	7.6	2.0	- -	6.8
	10	4.4	2.5	22.0	6.6
	15	2.5	3.0	- -	6.4
	17.5	1.0	3.0	26.0	6.4
Aug. 31	0	7.2	1.0	22.0	6.9
	5	7.2	1.0	- -	6.8
	6	3.0	2.5	- -	6.6
	8	3.8	- -	- -	- -
	10	3.7	3.0	24.0	6.4
	15	1.1	3.0	- -	6.4
	17.5	0.0	3.5	24.0	6.4
Sept. 7	0	6.7	2.0	24.0	6.8
	5	6.5	2.5	- -	6.8
	6	2.2	3.0	- -	6.2
	8	3.0	- -	- -	6.2
	10	2.7	4.0	- -	6.2

--Continued

TABLE IV. Summary of Chemical Factors in Lake Fort Smith of Selected Dates from December 28, 1938 to December 10, 1939. --(Continued)

Date	Depth in Meters	Oxygen ppm.	Free CO_2 ppm.	M. O. Alkalinity ppm.	pH
Sept. 7	12.5	1.4	- -	- -	6.4
	15	0.6	4.5	- -	6.4
	17.5	0.0	5.5	46.0	6.6
Oct. 1	0	7.5	1.0	31.0	6.8
	6	7.8	1.0	- -	6.8
	7	6.0	1.5	- -	6.8
	8	0.6	3.0	- -	6.4
	10	0.7	3.5	28.0	6.4
	12.5	0.6	4.0	- -	6.4
	15	Tr.	4.0	- -	6.4
	17	0.0	4.0	42.0	6.6
Oct. 29	0	8.7	0.5	20.0	6.6
	9	6.5	1.5	- -	6.4
	10	2.0	2.0	30.0	6.4
	11	0.3	2.0	- -	6.4
	12.5	0.1	2.5	- -	6.4
	15	0.0	3.0	- -	6.4
	17	0.0	3.0	39.0	6.4
Nov. 12	0	9.0	0.5	32.0	6.8
	17	8.8	0.5	29.0	6.8
Dec. 10	0	9.5	0.5	22.0	6.8
	17	8.4	0.5	23.0	6.8

Free Carbon Dioxide

Some free carbon dioxide was always present during the year 1939. Table IV shows the free carbon dioxide at significant meters for some representative dates for the year 1939. During the period when the lake was circulating the carbon dioxide varied from 0.5 to 2.0 parts per million; the highest reading during this time was on March 14, a week after the heaviest March rain. There was an increase in carbon dioxide in the water of the hypolimnion during stratification. The highest reading for the year was 5.5 parts per million, found on September 7 in the water just above the bottom.

Hydrogen-Ion Concentration

Table IV contains some selected hydrogen-ion concentration readings for the year 1939. The pH was always below 7.0. At the time of circulation the pH was usually 6.8 but varied from 6.6 to 6.4 after the heavy rains in March. When the water was stratified the pH near the bottom was usually at 6.4; in 2 instances, however, September 7 and October 1, the water at the bottom was 6.6, while that in 2 meters above was 6.4.

Alkalinity

The alkalinity in Lake Fort Smith was due entirely to bicarbonates. When the water was circulating the methyl orange alkalinity varied from 17 to 32 parts per million of calcium carbonate. The highest methyl orange alkalinity readings were found from September 7 up to the time of circulation; the methyl orange alkalinity reading at the bottom on September 7 was 46 parts per million. The range of methyl orange alkalinity on selected dates is summarized in Table IV.

NET PLANKTON

Seasonal Distribution

Total Net Plankton

The information presented here deals with the number and identification of species found in the various plankton groups, the seasonal occurrence of some of the more important species, seasonal variations of the main plankton groups and the relative abundance of the species to the total net plankton. No attempt was made in this investigation to enumerate the nannoplankton, therefore, all data given here deal with net plankton (mesoplankton) only.

Table V is a summary of the seasonal distribution of the various plankton groups for the year 1939, giving averages in numbers per liter for four depths, which are, surface, 5, 10 and 15 meters. Collections made at each meter, from the surface to the bottom, and those taken at various stations in the lake showed that data obtained from the above 4 levels give a reliable picture of the seasonal distribution and numbers of plankton; these data were obtained from averaging the above four levels at the deepest station. Although collections were made during the year 1938, this paper deals essentially with those of the year 1939, the former data being used only for comparison. In this study colonies were considered as one unit but the average number of individuals for each important species that forms colonies is presented in the discussion of that particular species.

From the standpoint of numbers of forms (species and varieties) the net plankters were well represented in Lake Fort Smith; qualitative and quantitative studies showed that there were 115 forms in 83 genera. These forms were poorly represented in numbers of individuals, averaging 106 organisms per liter in the collections of the year 1939. Of the 83 genera found in the lake, two *Kirchneriella* and *Conochilus*, comprised 56 per cent of the total net plankton. The Bacillarieae, often an important group in plankton counts, formed only 1.9 per cent of the total plankton. The Protozoa contributed only 0.7 per cent to the total.

No systematic study of the stream supplying Lake Fort Smith was attempted but, from occasional quantitative samples taken from the stream it is apparent that it also is high in numbers of species but low in individuals; many of the species found in the lake were also collected in the stream but not in numbers greater than those found in the lake. No collections were made during the late summer months when the stream ceases to flow.

Because of the few species in abundance in 1939 and the apparent influence of the late winter and spring rains the pulses were very irregular. During this investigation the lake had a tendency toward 2 main pulses; one extended from early October 1938 into April 1939 and another from the end of August through early September. In the year 1939 minor pulses occurred in May, June, October and early December.

The following plankters were found in qualitative and quantitative samples. Numbers, in parentheses, after the specific names indicate the references used in determination of species.

PHYTOPLANKTON

Myxophyceae

Anabaena sp.
Aphanocapsa rivularis (Carm.) Rab. (9,29,33)
Aphanothece sp.
Dactylococcopsis acicularis Lemm. (?) (9,29)
Gloeothece sp.
Lyngbya sp.
Microcystis sp.
Oscillatoria sp.

Chrysophyceae

Dinobryon bavaricum Imhof (24,29)
Dinobryon cylindricum Imhof (24)
Mallomonas sp.

Bacillarieae

Achnanthes sp.
Amphora sp.
Cyclotella sp.
Cymbella parva (W. Smith) Cleve (2,8,28)
Diatoma sp.
Epithemia zebra (Ehr.) Kűtz. (2,28)
Fragilaria crotonensis Kitton (1,28)
Fragilaria sp.
Gomphonema acuminatum Ehr. (2,8,28,39)
Gomphonema constrictum Ehr. (2,8,28,39)
Gomphonema olivaceum (Lyngb.) Kűtz. (2,8,28)
Gyrosigma sp.
Meridion circulare (Grev.) Ag. (1,8,28)
Melosira crenülata (Ehr.) Kutz. (?) (1,39)
Surirella elegans Ehr. (2,8,28,39)
Surirella robusta Ehr. (2,8,28,39)
Surirella splendida (Ehr.) Kütz. (2,28,39)
Synedra acus Kütz. (1, 28)
Synedra pulchella (Ralfs) Kütz. (1,8,28)
Synedra ulna (Nitzsch.) Ehr. (1,8,28)
Synedra sp.

Chlorophyceae

Ankistrodesmus sp.
Arthrodesmus octocornis Ehr. (30,38)
Bulbochaete sp.
Cladophora sp.
Closteriopsis longissima Lemm. (?) (18,29)
Closterium moniliferum (Bory) Ehr. (30,32,38)
Closterium sp.
Cosmarium botrytis (Bory) Menegh. (30,32,38)
Cosmarium contractum Kirchn. (30,38)
Cosmarium contractum var. *papillatum* W. & G. S. West (30)
Desmidium baileyi (Ralfs) Nordst. (26,30)
Desmidium swartzii Ag. (26,30,32,38)
Eudorina elegans Ehr. (7,23,29)
Golenkinia radiata Chod. (18,29)
Gonatozygon aculeatum Hastings (30)
Gonatozygon sp.
Gymnozyga moniliformis Ehr. (30)
Hyalotheca dissiliens (Smith) Bréb. (26,30,32,38)
Hyalotheca mucosa (Dillw.) Ehr. (26,30,38)
Kirchneriella obesa (W. West) Schmidle (18,29)
Micrasterias americana (Ehr.) Ralfs (30,32)
Micrasterias radiata Hass. (26,30,38)
Micrasterias radiosa var. *ornata* Nordst. (30)
Mougeotia sp.
Netrium sp.
Oedogonium sp.
Onychonema laeve (var. *latum* ?) W. & G. S. West (25,30)
Pediastrum duplex var. *gracillimum* W. & G. S. West (18,29)
Pleurotaenium trabecula (Ehr.) Någ. (30)
Sphaerocystis schroeteri Chod. (18,29)
Spondylosium planum (Wolle) W. & G. S. Smith (30,32)
Staurastrum arctiscon (Ehr.) Lund. (30)
Staurastrum chaetoceras (Schrőd.) Smith (30)
Staurastrum dickiei var. *maximum* W. & G. S. West (30)
Staurastrum floriferum W. & G. S. West (30)
Staurastrum megacanthum Lund. (30,38)
Staurastrum protectum var. *planctonicum* G. M. Smith (30)
Tetraspora sp.
Trochiscia sp.
Ulothrix subconstricta C. S. West (29)
Ulothrix zonata (Weber and Mohr) Kűtz. (7,29,37)

Volvox sp.
Xanthidium antilopaeum var. *minneapoliense* Wolle (30)
Xanthidium subhastiferum var. *toweri* (Cushm.) G. M. Smith (30)

Dinophyceae
Peridinium sp.

Euglenophyceae
Euglena proxima Dang. (34)
Phacus longicauda (Ehr.) Duj. (34)
Trachelomonas volvocina Ehr. (34)

ZOOPLANKTON

Protozoa
Arcella sp.
Cyclidium sp.
Codonella cratera (Leidy) (17,19)
Difflugia sp.
Epistylis sp.
Vorticella sp.

Rotifera[1]
Asplanchna sp
Collotheca mutabilis (Hudson) (6,14)
Conochilus unicornis Rousselet (6)
Euchlanis sp.
Gastropus hytopus Ehr. (6,14,15)
Keratella cochlearis (Gosse) (6,15)
Lecane luna (Müller) (6,12,15)
Monostyla sp.
Notholca longispina (Kellicott) (6,15)
Polyarthra euryptera Wierzejski (6)
Polyarthra trigla Ehr. (6)
Synchaeta pectinata Ehr. (?) (6,14)
Trichocerca cylindrica (Imhof) (6,16)
Trichocerca longiseta (Schrank) (16)

Crustacea

Cladocera
Alona quadrangularis (O. F. Müller) (35)
Bosmina longispina Leydig (?) (35)
Bosmina obtusirostris Sars (35)
Bosminopsis deitersi Richard (35)
Chydorus sphaericus (O. F. Müller) (35)
Daphnia longispina var. *hyalina* Leydig (35)
Daphnia sp.
Diaphanosoma leuchtenbergianum Fisher (35)
Simnocephalus vetulus (O. F. Müller) (35)

Copepoda[2]
Cyclops bicuspidatus Claus (10,21,35)
Cyclops leuckarti Claus (?) (10,21,35)
Cyclops modestus Herrick (21,35,36)
Cyclops prasinus Fisher (10,21,35)
Cyclops sp.
Diaptomus pallidus Herrick (20,35)

Phytoplankton

The phytoplankton of Lake Fort Smith was composed of 80 forms which constituted 67.3 per cent of the total net plankton. Although phytoplankters were well represented qualitatively, the following 5 genera, *Kirchneriella, Sphaerocystis, Cosmarium, Dinobryon* and *Staurastrum* accounted for the quantity during the year 1939. The average number of phytoplankton for the collections for that

[1]Nomenclature according to Harring (1913)

[2]Nomenclature according to Gurney (1933) and Ward and Whipple (1918)

year was 71 organisms per liter. This group showed one main pulse with variations within it following the heavy spring rains; it began in October 1938 and continued into April. A secondary pulse was present in May and June. The maximum for the main pulse was 324 units per liter and was found on January 22, 1939; the maximum for the secondary pulse was 60 units. When compared with pulses found in some other lakes the phytoplankton numbers of this lake were very low.

Myxophyceae

This group was represented by 8 species in 8 different genera. These accounted for 1.0 per cent of the total plankton for the year 1939. Only 3 species appeared in numbers during this investigation, namely:

Aphanocapsa rivularis (Carm.) Rab. This form was found on March 19, 1939 with an average of 28 colonies per liter.

Dactylococcopsis acicularis Lemm. (?) Found only in numbers during the months of June and July of 1938 with a maximum of 32 on June 16.

Gloeothece sp. Found only in numbers during the month of October in 1938 with a maximum of 33 per liter on October 9.

CHRYSOPHYCEAE

The Chrysophyceae made up 4.9 per cent of the total net plankton for the year 1939. Except for an occasional *Mallomonas* and *Dinobryon bavaricum* the entire quantity was formed by one species, *Dinobryon cylindricum*. During the year 1939 the latter species was most numerous in the month of May and reached a maximum of 52 colonies per liter on May 23. This species was again present in small numbers from January to the latter part of February and September through December. In the latter periods, except for one date, October 15, when the organisms reached 13 colonies per liter, the numbers were less than 10. In 1938 this form was found in small numbers from early October through December with one exception, November 6, when there were 23 colonies per liter. The average number of cells per colony was 32.

Bacillarieae

Qualitatively this is the second largest group but numerically it is one of the more poorly represented. The Bacillarieae amounted to only 1.9 per cent of the total net plankton. Of this percentage the genus *Synedra* made up 0.9 per cent. Analyses of the plankton of the stream supplying this lake showed that it also is rich qualitatively but poor quantitatively.

Chlorophyceae

This group of phytoplankton was the most important in both quality and quantity during the year 1939; the group is represented by 44 forms in 29 genera. The Chlorophyceae contributed 59 per cent to the total net plankton during the year 1939. As a matter of fact, 4 genera accounted for the greater share of the percentage attributed to the Chlorophyceae. One species, *Kirchneriella obesa*, formed 39 per cent of the total net plankton. Some Chlorophyceae were present in every month of the year. In 1939, the largest numbers were found from January through early April and from the middle of October through December; the greatest number, 314, was found on January 22. On two dates, within the above months, March 7 and 14, the numbers were less than 15 per liter and probably can be explained by the high turbidity and excessive rainfall during that time. Chlorophyceae were found, in numbers less than 15 per liter, during the remaining months of 1939 with the exceptions of June, early July and late August. In the year 1938 the Chlorophyceae were present in numbers from early October through December reaching a maximum of 44 on November 20.

Kirchneriella obesa (W. West) Schmidle. This species was the most important member of the group Chlorophyceae; it accounted for 39 per cent of the total net plankton and about 2/3 of the total Chlorophyceae. During 1939, with the exception of the time around March 7 and 14 it was abundant from the end of December, 1938 to April 8, 1939, during which time the averages ranged from 2 colonies to 254. On March 7 only 11 colonies per liter were found and again on March 14 only 2. This decline in colonies was probably due to the high turbid-

ity in the lake at this time. In the year 1939 none had appeared by December 10 while during 1938 they were encountered by October but were not present in quantities larger than 6 colonies per liter until November 20 when 20 were present. The largest number found in the winter of 1937-38 was 2 colonies per liter on January 8.

Sphaerocystis schroeteri Chodat. This species contributed 7.6 per cent to the total plankton. It was found in numbers during the months of June and July and reached its maximum of 42 colonies on June 27, 1939. This species, in 1939, was also present from January to early April and from the latter part of August through December, but was found in numbers only in January, early February and December. In the year 1938 this form began to appear in numbers in the early part of October reaching a maximum of 41 on December 28.

Cosmarium contractum No attempt was made to separate the 2 forms of this species in the plankton counts. These two made up the third most important group of Chlorophyceae in that they accounted for 7.3 per cent of the total net plankton. This genus appeared in significant numbers during the year 1939 from mid-October through December. In the same year it was also abundant from the first of January through February. The maximum number, 66 per liter, appeared on December 10, 1939; during the rest of this pulse the averages varied from 9 to 27 per liter. Also, in this year the genus made an appearance during June and July but not ever in numbers more than 11 per liter. In the year 1938 it was found in numbers only from October through December with a maximum of 20 per liter on November 20. *Cosmarium botrytis* made only an occasional appearance.

Staurastrum. In quantitative work this genus was considered as one group and no attempt was made to separate the species. This is the fourth important genus in the Chlorophyceae forming 4.0 per cent of the total net plankton. During the year 1939, members of this genus were present from early June to the end of December and from January to early March but appeared in significant numbers only from the end of August to early December. During this time they appeared in numbers greater than 15 per liter only on two occasions; on August 24 there were 20 per liter and on December 10 there were 49. At no time during 1938 did this genus appear in numbers greater than 3 per liter.

Dinophyceae

This group was represented by one genus and accounted for 0.5 per cent of the total net plankton. This genus, *Peridinium*, appeared in small numbers in collections from the latter part of August to early December with a maximum of 13 individuals per liter on August 31, 1939.

Euglenophyceae

The Euglenophyceae were found only in qualitative samples and consisted of 3 species in 3 genera.

Zooplankton

The Zooplankton was represented by 35 species and composed 32.7 per cent of the total net plankton. The average number of Zooplankton for the collections of the year was 35 per liter. Again, as in the Phytoplankton, a very few species contributed to most of the precentage of the Zooplankton. This group showed one main pulse during the year 1939; it extended from the end of August through the first week of September with a maximum of 401 on September 7, 1939. With the exception of the Protozoa, the Zooplankton compare much more favorably with more productive lakes than do the Phytoplankton.

Protozoa

This group was represented by 6 species in 6 genera. This is one of the less important groups numerically, contributing only 0.7 per cent to the total net plankton.

Rotifera

The Rotifera was the important Zooplankton group forming 21.4 per cent of the total net plankton. One species, Conochilus unicornis, comprised 17 per cent of the total plankton. This group was represented by 11 genera and 13

species. Some individuals of this group were found in every month of the year except March. The largest numbers were found during the months of August and September in the year 1939 with a maximum of 381 on September 7. They were also more abundant in early April with a maximum of 28 on April 8. They increased in numbers on three other dates: May 23 with 27 per liter, June 23 with 19 and June 27 with 34. At all other times there were less than 10 per liter.

Conochilus unicornis Rousselet. This was the most important species of the Rotifera. It accounted for 17 per cent of the total net plankton, appearing in the first week of April and remaining until the end of September. Except for 4 collecting dates it never exceeded 10 organisms per liter. These four dates and average numbers were: May 23, 27 individuals; June 27, 32; August 31, 141; and September 7, 373.

Synchaeta pectinata Ehr. (?) This was the second species of importance and formed 1.9 per cent of the total plankton. This species appeared in December and, with March an exception, continued through June. During this period it reached its maximum of 23 on April 8 and never exceeded 3 organisms on any other date. It again appeared in September and October reaching a maximum of 6 on October 15.

Polyarthra. No attempt was made to separate the two species quantitatively. This was the third genus of importance forming 1.1 per cent of the total net plankton. It was present in numbers of less than 3 organisms per liter in each month with the exceptions of March and June. In March none were present and on June 23, 1939, 14 organisms per liter were found.

Keratella cochlearis (Gosse). This species appeared in collections from the end of June through December of the year 1939; it was also present in January of that year. A maximum of 4 was found on July 21, 1939.

Cladocera

This group contributed 3.5 per cent to the total net plankton and was represented by 9 forms. The Cladocera showed three increases during the year 1939. The first extended from January into April with the organisms showing a decline during March near the end of the turbid period. The maximum of 5 was found on March 7 at the beginning of the turbid period. The second extended from June through July having a maximum of 6 on June 27 and July 15. The third extended from the beginning of September into December; the maximum number, 22, was found on December 10. In 1938 they were abundant from the beginning of October to the end of November with a maximum of 7 on October 23, during which year they were also present in larger numbers in January, June and July.

Daphnia. Although 2 species were present, *Daphnia longispina* was the dominant form. In counting, the two species were enumerated together. This genus formed 2.2 per cent of the total net plankton. During the year 1939 *Daphnia* showed a tendency toward 3 pulses. The first extended from January into February with a maximum of 3 on January 8. The second extended from the first of June through the month of July with a maximum of 6 on July 15. The third extended from early September through the first of December with a maximum of 19 on December 10. In 1938 they were found in increased numbers in July and again from the beginning of October through the month of November; they were also present in January.

Bosmina. The 2 species of *Bosmina* were not separated quantitatively. This genus accounted for 0.8 per cent of the total net plankton. It showed two pulses. One ranged from the middle of February into April with a reduction during March. The maximum at this time was 3 on April 8. The other extended from September through October with a maximum of 4 on October 15. This form was unimportant in 1938.

Diaphanosoma leuchtenbergianum Fisher. This species made up 0.4 per cent of the total net plankton. It appeared in numbers only during October reaching a maximum of 6 per liter on October 15.

Copepoda

In the Zooplankton this was the second group of importance in numbers of individuals per liter. The Copepoda contributed 7.1 per cent to the total net plankton. Two genera and six species of Copepoda were identified and were pres-

ent in every month of the year. In all months except March and May they were present in numbers greater than 3 per liter. During the months of September and October they showed a definite pulse having the following numbers per liter on the respective dates: September 7, 12; September 24, 16; October 1, 56; October 15, 24; and October 29, 26.

Cyclops. Although *Cyclops prasinus* was the most abundant form, all 5 species were counted as one group. This genus accounted for 2.0 per cent of the total net plankton. Even though *Cyclops* occurred all during the year the numbers started to increase beginning about the middle of June to a definite pulse in September and October. Dates and numbers of individuals per liter during those months were: September 7, 4; September 24, 2; October 1, 17; October 15, 6; and October 29, 8.

Diaptomus pallidus Herrick. *Diaptomus* was the other important genus in the Copepoda contributing 1.1 per cent to the total net plankton. This genus followed the same pattern as Cyclops being present throughout the year. It showed an accumulating of numbers beginning the first of July and had a definite pulse from September through December. Dates and numbers of individuals per liter during the latter months were: September 7, 3; September 24, 2; October 15, 3; October 29, 2; and December 10, 4.

Nauplii. Nauplii formed 4.0 percent of the total net plankton. Some were present in every sample throughout the year 1939 but in quantities less than 6 per liter with the exceptions of September and October. Dates and numbers of individuals per liter in September and October were: September 24, 12; October 1, 39; October 15, 15; and October 29, 16.

SUMMARY

1. Lake Fort Smith is an artificial lake formed by damming a valley in the Boston Mountains and is located twenty-five miles northeast of the city of Fort Smith, Arkansas. Very small amounts of rooted aquatic plants were present in 1939 due in part to the steep slopes of the basin and the newness of the lake. The lake was in its fourth year of impoundment.

2. The lake has a shore line of 7.3 miles, an area of 525.5 acres, shore development of 2.29, volume development of 0.95 and a mean depth of 22.94 feet.

3. During 1939 the lake had one stratification and circulation period. The minimum surface temperature in the winter was 5.2°C. The average bottom temperature for the summer was 10.98°C.

4. Oxygen free water first appeared near the bottom on August 31 and remained until November. Alkalinity was due entirely to bicarbonate and it varied from 17 to 46 parts per million. Some carbon dioxide was present throughout the year 1939.

5. Heavy late winter and early spring precipitation and its resulting turbidity in the lake had a harmful influence on the productivity of Phytoplankton, especially *Kirchneriella obesa*. Heavy rains at other times during the year had little effect on turbidity in Lake Fort Smith

6. Additional information concerning temperatures, transparency, dissolved oxygen, carbon dioxide, hydrogen-ion concentrations, alkalinity and morphometric measurements is presented.

7. In numbers of forms (species and varieties) the net plankters were well represented in Lake Fort Smith; there were 115 forms in 83 genera. The number of forms in the different plankton groups were: Myxophyceae, 8 species; Chrysophyceae, 3; Bacillariae, 21; Chlorophyceae, 44 forms; Dinophyceae, 1 species; Euglenophyceae, 3; Protozoa, 6; Rotifera, 13; Cladocera, 9; Copepoda, 6.

8. In numbers of individuals the net plankters were poorly represented in Lake Fort Smith; the average number of individuals per liter for the collecting dates for 1939 was 106. Of the 83 genera in the lake, two, *Kirchneriella* and *Conochilus*, formed 56 per cent of the total net plankton; 12 genera accounted for 87.96 per cent. The percentages for the individual plankton groups were Myxophyceae, 1.0 per cent; Chrysophyceae, 4.9; Bacillariae, 0.9; Chlorophyceae, 59; Dinophyceae, 0.5; Protozoa, 0.7; Rotifera, 21.4; Cladocera, 3.5; Copepoda, 7.1.

9. The Phytoplankton pulse began in October 1938 and continued into April 1939. The Zooplankton pulse extended from the end of August, 1939 through the first week in September. The seasonal cycles of some individual species of plankters are presented.

10. The average number of Phytoplankton per liter for the collecting dates for the year 1939 was 71, the maximum number 324, the minimum 3. The average number of Zooplankton for the collecting dates for the year 1939 was 35 per liter, the maximum 401, the minimum 1.

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TABLE V

Averaged Number of Net Plankters Per Liter for Surface, 5, 10 and 15 Meters.

Group	Dec. 28 1938	Jan. 8 1939	Jan. 22	Feb. 5	Feb. 12	March 7	March 14	March 19	Apr. 2	Apr. 8	Apr. 23	May 7
Myxophyceae	0	0	1	0	0	0	0	28	1	0	1	0
Dinobryan cylindricum	*7*	*6*	*8*	*3*	*7*	*0*	*0*	*0*	*0*	*0*	*0*	*27*
Chrysophyceae	9	6	9	3	7	0	0	0	0	0	0	27
Bacillarieae	12	0	0	0	4	1	0	0	0	1	6	0
Dinophyceae	0	0	0	0	0	0	0	0	0	0	0	0
Kirchneriella obesa	*130*	*121*	*254*	*166*	*216*	*11*	*2*	*177*	*231*	*99*	*1*	*0*
Sphaerocystis schroeteri	*41*	*22*	*33*	*1*	*8*	*0*	*0*	*1*	*1*	*0*	*0*	*0*
Cosmarium contractum	*22*	*21*	*27*	*10*	*18*	*1*	*0*	*0*	*0*	*1*	*0*	*0*
Chlorophyceae	193	164	314	177	243	12	3	178	232	100	1	1
TOTAL PHYTOPLANKTON	214	170	324	180	254	13	3	206	233	101	8	28
Protozoa	2	1	2	1	0	0	0	1	1	0	1	0
Conochilus unicornis	*0*	*0*	*0*	*2*	*0*	*0*	*0*	*0*	*1*	*4*	*0*	*6*
Synchaeta pectinata (?)	*3*	*1*	*2*	*2*	*1*	*0*	*0*	*0*	*16*	*23*	*0*	*1*
Rotifera	4	2	2	5	1	0	0	0	17	28	0	9
Cladocera	1	4	2	2	3	5	0	1	1	4	0	0
Copepoda	7	4	4	4	6	1	1	1	1	4	1	1
TOTAL ZOOPLANKTON	14	11	10	12	10	6	1	3	20	36	2	10
TOTAL NET PLANKTON	228	181	334	192	264	19	4	209	253	137	10	38

Group	May 14	May 23	June 7	June 15	June 23	June 27	July 6	July 15	July 21	July 28	Aug. 11	Aug. 17
Myxophyceae	0	0	0	0	0	4	0	0	0	0	0	1
Dinobryon cylindricum	*36*	*52*	*0*	*1*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Chrysophyceae	36	52	0	1	1	1	0	0	0	0	0	1
Bacillarieae	0	7	1	2	4	6	1	2	1	3	4	1
Dinophyceae	0	0	1	0	0	0	0	0	0	0	0	0
Kirchneriella obesa	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*1*

--Continued

TABLE V --(continued)

Group	May 14	May 23	June 7	June 15	June 23	June 27	July 6	July 15	July 21	July 28	Aug. 11	Aug. 17
Sphaerocystis schroeteri	*0*	*1*	*4*	*15*	*34*	*42*	*15*	*12*	*0*	*1*	*0*	*0*
Cosmarium contractum	*0*	*0*	*5*	*10*	*6*	*6*	*1*	*1*	*11*	*1*	*0*	*0*
Chlorophyceae	0	1	12	27	41	49	17	14	11	3	1	10
TOTAL PHYTOPLANKTON	36	60	14	30	46	60	18	16	12	6	5	13
Protozoa	0	0	0	1	0	1	0	1	0	0	1	0
Conochilus unicornis	*1*	*27*	*3*	*1*	*3*	*32*	*1*	*1*	*1*	*1*	*10*	*8*
Synchaeta pectinata (?)	*1*	*0*	*1*	*3*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Rotifera	2	27	5	4	19	34	2	5	6	4	12	11
Cladocera	1	0	1	2	4	6	2	6	4	1	0	1
Copepoda	2	1	3	7	2	2	7	5	5	5	7	4
TOTAL ZOOPLANKTON	5	28	9	14	25	43	11	17	15	10	20	16
TOTAL NET PLANKTON	41	88	23	44	71	103	29	33	27	16	25	29

Group	Aug. 24	Aug. 31	Sept. 7	Sept. 24	Oct. 1	Oct. 15	Oct. 29	Nov. 12	Nov. 26	Dec. 10
Myxophyceae	0	0	0	0	0	0	0	0	0	0
Dinobryon cylindricum	*0*	*0*	*4*	*0*	*0*	*13*	*2*	*1*	*0*	*1*
Chrysophyceae	1	0	4	0	0	13	2	1	0	3
Bacillarieae	1	2	1	1	1	2	2	1	0	4
Dinophyceae	0	13	0	1	0	1	2	0	0	0
Kirchneriella obesa	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Sphaerocystis schroeteri	*1*	*7*	*1*	*3*	*0*	*3*	*2*	*3*	*3*	*21*
Cosmarium contractum	*0*	*1*	*1*	*2*	*2*	*9*	*10*	*12*	*18*	*66*
Chlorophyceae	26	17	10	9	9	26	25	30	30	137
TOTAL PHYTOPLANKTON	28	32	15	11	10	42	31	32	30	144
Protozoa	0	1	2	0	0	1	2	8	2	1
Conochilus unicornis	*11*	*141*	*373*	*0*	*0*	*1*	*0*	*0*	*0*	*0*
Synchaeta pectinata (?)	*0*	*0*	*1*	*0*	*4*	*6*	*1*	*1*	*0*	*0*
Rotifera	14	145	381	3	6	9	4	2	1	3
Cladocera	1	1	6	7	13	12	4	2	4	22
Copepoda	11	6	12	16	56	24	26	4	8	7
TOTAL ZOOPLANKTON	26	153	401	26	75	46	36	16	15	33
TOTAL NET PLANKTON	54	185	416	37	85	88	67	48	45	177

PHYSIOLOGY OF LEAF ABSCISSION[1]*

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The mechanism of the abscission process of mature leaves either induced by natural plant processes or by application of chemical defoliants is not fully understood. A study of the role of chemical defoliants in the abscission process may contribute considerable information toward the elecidation of this mechanism. With additional knowledge it may be possible to develop more efficient defoliants which will react under a wider range of plant and environmental conditions. This study was concerned with the action of chemical defoliants as they stimulate the initiation of the abscission process. A series of experiments was conducted to determine whether cotton leaves treated with chemical defoliants release ethylene. Another series of experiments was conducted to determine the effect of ethylene on the abscission of leaves of young cotton plants.

Methods and Materials

Cotton plants (*Gossypium hirsutum L.*) varieties Lockett 140, Deltapine 15, and Arkot 2-1, were employed in these greenhouse studies.

The defoliants were applied with a hand atomizer at a constant pressure of fifteen pounds. Concentrations found most satisfactory in earlier screening trials were employed.

In experiments 3, 5, and 6 the "pea test" described by Pratt and Biale (4) was employed for determining the release of ethylene from biological material. The gaseous components liberated from cotton leaves after treatment with chemical defoliants were collected in stoppered 2-liter suction flasks. Leaves were harvested 24 hours following applications and confined for 48 hours in the flasks. The technique of Hansen and Hartman (3) was employed for removing gases other than ethylene which cause similar growth responses in the pea test. This growth response is described as a "triple response". It consists of inhibition of growth in length, increase in thickness, hypertrophy, and the shift from negative geotropism to diageotropism in etiolated Alaska pea seedlings. After removal, the remaining gas sample was passed by water displacement into a bell jar containing the etiolated pea seedlings or other test plants.

As procedures varied among the different experiments, additional information on methods and materials will be cited under the appropriate experiments.

Results

Experiment Number 1.

Application of an aqueous solution of ethylene contained in a vial surrounding a portion of the petiole of a leaf caused abscission of the treated leaf and also of leaves at nodes above and below the treated leaf. When more than one-half of the leaf blade was removed, less of the abscission stimulus was translocated to the adjacent nodes, since a smaller number of leaves abscised. Where 1/4 or less of the leaf blade remained, the treated leaves abscised within 48 hours. The rate of abscission was much slower than 1/2 or more of the leaf remained.

Experiment Number 2.

Portions of all the leaf blades were excised from thirty day old cotton seedlings. These seedlings were then placed under bell jars containing ethylene gas. Abscission was accelerated by the removal of any portion of the blade.

[1]Contribution from the Department of Agronomy, University of Arkansas.

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Experiment Number 3.

A one per cent solution of formulations containing each of the following defoliant chemicals was applied to three mature cotton plants: monosodium cyanamid, potassium cyanate, sodium monochloroacetate, sodium chlorate, ammonium thiocyanate, disodium 3,6-endoxohexahydrophthalate, and AC-D-85, experimental defoliant, identity confidential. Gas samples collected in the manner described above were introduced into bell jars containing etiolated pea seedlings, a young tomato plant, and a cotton seedling at the 6-leaf stage.

Leaf epinasty on the tomato plant was evident within 24 hours from treatments of disodium 3,6-endoxohexahydrophthalate, sodium monochloroacetate, sodium chlorate pentaborate, and AC-D-85. Epinasty occurred within 72 hours from the remaining treatments. In all the treatments the leaves showing the most severe epinasty had abscised within 84 hours.

The cotyledons of the cotton seedlings had abscised within 72 hours from the following treatments: AC-D-85, Disodium 3,6-endoxohexahydrophthalate, sodium monochloroacetate, monosodium cyanamid and sodium chlorate pentaborate. By 96 hours the primary leaves of cotton seedlings were beginning to abscise from these same treatments.

The severity of the triple response manifested by the etiolated pea seedlings varied with the treatment, but is was evident in all treatments. The order of decreasing severity of response was as follows: AC-D-85, monosodium cyanamid, disodium 3,6-endoxohexahydrophthalate, sodium monochloroacetate, sodium chlorate pentaborate, potassium cyanate and ammonium thiocyanate. These responses appear identical with those caused by small concentrations of pure ethylene. Since other gases causing similar effects were removed by accepted methods (3), the active emanation from the defoliant treated leaves is thought to be ethylene. The percentage of defoliation obtained by treatment of entire plants (in duplicate) with similar applications of these defoliants varied directly with the degree of the triple response in the pea test.

Experiment Number 4.

This experiment was designed to compare the effects of ethylene and the gas liberated from defoliant treated leaves on leaf absicission from cotton seedlings.

Mature cotton plants were sprayed with solutions of monosodium cyanamid and disodium 3,6-endoxohexahydrophthalate. Twenty-four hours later, a twenty-five gram sample (fresh weight) of leaves was collected from each treatment, and placed under a six liter bell jar containing three 30 day old cotton seedlings with approximately 7 leaves per plant. At the same time, a watch glass containing four milliliters of saturated aqueous solution of ethylene was placed under another bell jar containing three 30 day old cotton seedlings. Within two days some primary leaves and cotyledons had abscised from plants treated with ethylene. The emanation from the leaves treated with the disodium 3,6-endoxohexahydrophthalate caused abscission of the cotyledons by the fourth day, and abscission of all the leaves by the sixth day. The rate of abscission was slower where the plants were confined with the monosodium cyanamid treated leaves. Only the cotyledons had abscised by the sixth day although definite breaks had begun at the abscission zones of the primary leaves.

Experiment Number 5.

Different portions of the upper surface of the primary leaf blades of mature cotton plants were treated with a one per cent solution of monosodium cyanamid. The defoliant was applied through a pipette with a camel hair brush attached to the tip to control placement of the solution on the blade. After 24 hours, or when the action of the defoliants on the leaves first became evident, ten leaves from each treatment were harvested and placed in flasks for collection of gases. This gaseous emanation was then employed in the pea test. The greatest response was obtained where the entire leaf had been treated. Progressively smaller responses were obtained when 3/4, 1/2, and 1/4 of the leaf surface was treated with defoliant. A greater response was obtained when the basal one-half of the leaf was treated with defoliant as compared with the treatment of the apical one-half or lateral one-half of the leaf.

Experiment Number 6

The leaves were treated in the same manner as in experiment number five. However, when the leaves were collected, the treated portions of the individual leaves were separated from the untreated portions. Gas samples were then collected from both the treated and untreated portions of the leaves, and these samples were again employed in the pea test. When one-half, or less, of the leaf blade was treated with defoliant, the untreated portion of the blade gave no response in the pea test. In all cases, the treated portion of the leaf produced a greater response than the untreated portion.

Experiment Number 7.

An experiment was conducted to determine if ethylene is released from a defoliant treated leaf in quantity sufficient to cause abscission of a similar leaf if both were enclosed in the same container. Leaves were selected for uniformity in size and position on the plant. Twenty-four hours after treatment of single leaf blades with monosodium cyanamid or 3,6-endoxohexahydrophthalate, each treated blade was excised and placed in a sealed quart Mason jar with the blade of a leaf attached to an untreated plant. Four milliliters of an aqueous solution of ethylene was similarly confined with the blade of a leaf attached to an untreated plant. Each treatment was duplicated. The leaves confined with the saturated aqueous solution of ethylene abscised within three days. The leaves confined with single leaves treated with the defoliants abscised within five days.

Discussion

Ethylene has long been known to stimulate the abscission of leaves of plants. Brown and Addicott (1) found that the middle lamellae are broken down in the abscission zones when ethylene is in contact with explants of the black valentine bean. They state that this breakdown can occur without the remainder of the cell becoming involved. This suggests that one of the roles of ethylene in the abscission process may be the dissolution of the middle lamellae.

It was shown in experiments 1 and 7 that the stimulus from ethylene may be translocated. Treating a leaf petiole with an aqueous solution of ethylene caused the treated leaf and adjacent untreated leaves to abscise. Abscission of the treated leaf occurred when only the leaf blade was subjected to ethylene.

Ethylene is used commercially to hasten ripening or onset of maturity of citrus fruit. When cotton leaves are treated with ethylene, they become yellow and exhibit a mellowing effect, resembling natural maturity or senescence. Gawadi and Avery (2) state that natural abscission is the ultimate result of senescence of cells of the abscission organs. Since young leaves abscise when subjected to ethylene, the action of ethylene could be interpreted as causing premature senescence.

Shoji, Addicott and Swets (5) found that there is a reduction of the auxin concentration in the leaf stalk of leaflets of bean plants when they become senescent.

Gawadi and Avery (2) have proposed the framework of a theory concerning the relationship between a plant hormone balance and abscission, the essence of which follows: Immature leaves contain a relatively abundant supply of hormone (presumably auxin). As the leaf matures and approaches senescence the supply of this hormone diminishes. Thus, it is possible that the abscission behavior of plants is a matter of relative unbalance between a hormone and some other substance in the leaves or other abscising organs.

The present study seems to lend support concerning the role of auxin as a possible anti-abscission agent, since removal of a portion of the leaf blade accelerated the abscission of leaves treated with ethylene.

Leaves treated with any one of the seven defoliants were shown to produce a gaseous emanation which was ethylene or a substance which reacts similarly. It seems plausible, on the basis of the diverse chemical structure of these chemical defoliants, to postulate that this emanation is the active agent in inducing the abscission process.

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BREEDING CEREAL CROPS FOR THE CONTROL OF DISEASES*

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In the world of microbes, this is a shifting and fluctuating universe. This is particularly true for those parasitic microbes which attack cereal crops so lowering the quality and yields of such crops that large regions of the world are quite often threatened with starvation.

Were it not for the shifting nature of these parasites, the problem of controlling the diseases which they induce would be much simplified. If the fungi called rusts and smuts would remain fixed and unvarying in their ability to parasitize certain varieties while leaving other varieties free from serious attacks, the growers and breeders of such crops would merely need to note which varieties remain free from disease and give good yields and reject those that do not. Unhappily, however, there is no variety of wheat, oats, barley, or rye which has remained resistant to these parasites for any long time. The reason for this is that when any new variety resistant to the current races of rusts and smuts is grown on large acreage, a new race of rust or smut appears sooner or later which attacks this variety.

As an illustration of the shifting nature of these parasites, we may take the disease known as crown rust of oats, a disease which has engaged and often enraged your speaker for over 16 years. In 1935, there were 33 races of crown rust known on the North American continent. By 1936, 44 races were identified; by 1937, 46 races; by 1940, 56 races; by 1945, 85 races; and by 1951, 101 races. In 1936, 3 races were prevalent in Arkansas, predominantly race 1. In 1937, a new race appeared, race 45, which gradually became a first rate menace and replaced race 1 in prevalence and destructiveness.

In 1949 still another new race of crown rust was discovered in Arkansas which threatens nearly all the commercial varieties now commonly grown in this state. It is tentatively listed as race 101.

In 1936, the Arkansas Agricultural Experiment Station initiated a breeding program primarily aimed at controlling crown rust, smut, and other diseases of oats. At that time this state had the unenviable record of producing an average yield of 20 bushels to the acre, one of the lowest state yields in America. The state utilized an average of about 100,000 acres for growing oats. The result was that millions of dollars were spent annually by our livestock producers to purchase feed out of the state.

Not a single oat variety commonly used in 1936 had sufficient disease resistance coupled with enough winter hardiness to guarantee satisfactory yields. Varieties which had considerable winter hardiness possessed almost no rust or smut resistance, while those that did have disease resistant qualities had such little winter hardiness that they could not be depended upon, especially in the hilly parts of the state.

The breeding problem that confronted us was essentially one of combining disease resistance with good winter hardiness. We therefore started in 1936 by making several thousand crosses, utilizing disease resistant varieties which had no winter hardiness as part of the parentage and disease susceptible varieties with considerable winter hardiness as the other parent.

Selections from the progenies of these crosses were begun in the F_2 generation. These were tested for disease resistance by artificially inoculating them in the greenhouse and in the field and by subjecting them to natural epidemics. Over 10,000 of such selections were tested in 1938. They were also tested for winter hardiness under natural conditions.

One of these selections first revealed certain outstanding qualities in 1940 following an exceptionally severe freeze on November 11. While most of the selections were completely killed by this freeze, this selection came through with very little injury and produced a yield of over 90 bushels to the acre. In

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addition to its winter hardiness it proved to be uniformly resistant to the races of rust and smut prevalent in Arkansas at that time. After several years of additional testing, it was released to Arkansas growers in 1944 and named, "Traveler."

This variety has had much to do with the marked increase in oat acreage in this state and in lifting the state average yield of 20 bushels to 30 or more bushels. It is at present occupying about one-third of the state oat acreage and is also being grown in adjoining states.

But Traveler is now meeting the fate of all new cereal varieties. In fact, the very year when it was first released, we discovered a new disease, Helminthosporium blight, to which this variety was susceptible. Fortunately, we also discovered that this disease does very little damage when the temperature falls below 70° F. and we soon found that by rotating crops and treating the seed with an organic mercury compound, the disease is readily controlled. Thus by seeding two or three weeks later in the fall, when the mean temperature is likely to be below 70°, and by treating the seed and rotating crops, Traveler still gave good yields. In fact yields of 90 to 100 bushels per acre were not very rare for this variety last year.

But in addition to its susceptibility to Helminthosporium blight, we have found new races of smut which attack Traveler, a new virus disease, and perhaps worst of all, a new race of crown rust, race 101 (mentioned previously) to which it is susceptible.

Fortunately we now have other varieties coming up in our breeding plots which offer resistance to these new diseases and one of these will probably be released this fall. In fact, back in 1937, as soon as we found crown rust race 45 present in the state, we immediately began looking for resistance to this race and the older races, and when Helminthosporium blight, new smut races, red spot mosaic, and race 101 appeared, a search was immediately begun in our own breeding material as well as that available from other breeders for resistance to these new diseases. Up to the present we have been able to find each new disease before it became very prevalent and have thus been able to anticipate the need for new varieties bred for resistance to the new as well as the old parasites. But it has meant constant work, constant vigilance, and no end to the breeding program.

Truly these microbes are shifty enemies.

EFFECT OF DIFFERENT IONIC RATIOS OF NUTRIENTS ON THE GROWTH RESPONSE OF YOUNG COTTON PLANTS[1]*

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Plant nutrition has received the attention of investigators for almost three centuries. Satisfactory plant growth on synthetic mineral-nutrient solutions was attained nearly a century ago. At present, fifteen elements are considered to be essential for plant growth.

Tottingham (7), Shive (6), Hoagland (3), and others have undertaken studies to formulate the best nutrient solutions for plant growth. Kuzmenko, et al. (4) have reported that the yield of cotton was less when cotton plants were grown to maturity on Hellriegel's nutrient solution containing a 1-1-1 ratio of N-P-K than when grown on a 1-4-1 ratio until flowering, followed by 4-1-4 to maturity. Olsen (5) found that the rate of absorption of ions from a nutrient solution is influenced by the ratio between concentrations of ions in the nutrient solution, but not by their absolute concentration.

This investigation was initiated to determine the effect of different ionic ratios of N-P-K on the growth and yield of cotton. The effect of ionic ratio on growth and development during the period from germination to square (flower bud) formation is reported herein.

Methods and Materials

The experiment was performed in the greenhouse. Each treatment consisted of three replications or pots. Seeds of cotton (*Gossypium hirsutum* L., variety Arkot 2-1) were planted on January 9, 1951, in six inch pots containing ten parts of sand, one part soil, and a half part manure compost. All except the two best seedlings were removed from each pot on January 18.

Equal volumes of nutrient solution were applied to each pot. As the plants increased in size, larger volumes of solution were supplied. During the 54-day period, 2,075 milliliters of nutrient solution was added to each pot. Tap water was supplied as needed to replenish losses by transpiration and evaporation. Wilting was kept to a minimum. The pots were flushed at weekly intervals as the plants became older and received larger quantities of nutrients. Flushing was kept to a minimum at other times.

The ionic ratios employed and the quantities of salts in the nutrient solutions are given in Table 1. All of the essential mineral elements were added as chemically pure salts, except copper which was assumed to be present in sufficient quantity in the distilled water used in preparing the nutrient solutions. The molar concentration of nitrogen, phosphorus, and potassium in the 1-1-1 ratio was 0.005.

Results

A comparison of some of the plant characteristics after 54 days growth on the ionic ratios is found in Table 2. Two series of plants were given the 1-2-1 ratio, thus two sets of data are recorded under that ratio.

The number of the node on the main stem at which the first visible square developed was recorded for each plant. The cotyledonary node was designated node "one". These data are presented in Table 3. The analysis of variance test indicated statistical significance between treatments but not between plants.

Plants which produced fruiting branches at the lower nodes also developed visible squares earlier, except for those plants on the 1-4-1 ratio.

[1]Contribution from the Department of Agronomy, University of Arkansas.

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Table 1. Composition of Nutrient Solutions.

Salt	Ratio of N-P-K				
	1-1-1	1-2-1	1-4-1	2-1-2	3-0.2-1.2
	Gm./1.	Gm./1.	Gm./1.	Gm./1.	Gm. / 1.
$Ca(NO_3)_2 \cdot 4H_2O$	0.472	0.472	0.472	0.708	0.950
KCl	0.075	0.075	0.075	0.224	-
KH_2PO_4	0.545	0.545	0.545	0.545	-
KNO_3	-	-	-	0.303	0.610
$NaH_2PO_4 \cdot H_2O$	-	0.690	2.071	-	-
$NH_4H_2PO_4$	0.115	0.115	0.115	0.115	0.120
$MgSO_4 \cdot 7H_2O$	0.400	0.400	0.400	0.400	0.400
$FeSO_4 \cdot 4H_2O$	0.010	0.010	0.010	0.010	0.010
H_3BO_3	0.0006	0.0006	0.0006	0.0006	0.0006
$MnSO_4 \cdot H_2O$	0.004	0.004	0.004	0.004	0.004
$(NH_4)_6Mo_7O_{24} \cdot 4H_2O$	0.005	0.005	0.005	0.005	0.005
$ZnSO_4 \cdot 4H_2O$	0.002	0.002	0.002	0.002	0.002
Initial pH of solution	5.1	4.9	4.8	5.0	4.9

Table 2. Comparison of Plants Maintained on Different Ionic Ratios of Nitrogen, Phosphorus, and Potassium for 54 Days after Planting.

Plant character	Ratio of N-P-K				
	1-1-1	1-2-1	1-4-1	2-1-2	3-0.2-1.2
Ave. height of 6 plants (centimeters)	36.2	45.2 41.2	33.3	45.5	46.3
No. of plants with a visible square after 54 days growth	1	4* 3	0	4	6
Color of leaves	Very pale green	Pale green	Very pale green	Green	Dark green
Color of stems	Pale green	Pale green	Pale green	Green	Dark green

*Three plants in this series produced visible squares earlier than any of the other plants in this experiment. Squares approximately five milli-meters in in width were evident 48 days after planting.

Table 3. Influence of Nutrient Ratio on Nodal Position Along Main Stem at which the First Square Developed.

	Ratio of N-P-K				
	1-1-1	1-2-1	1-4-1	2-1-2	3-0.2-1.2
Range in node number	8-10	7-8 7-9	7-8	8-10	7-8
Average node number (Average of 6 plants)	8.7	7.3 8.0	7.8	9.0	7.5

L. S. D. between treatment means for 5% level is 0.96; for 1% level is 1.30.

Discussion

Tabulation of the composition of nutrient solutions employed in solution culture studies reveals some widely divergent ionic ratios. Shive's "best" and "next best" solutions and the solutions developed by Hildebrandt, Riker, and Duggar (2) for the growth of excised tissues of sunflower and tobacco are good examples. Certain plants seem to grow well on one ratio and not so well on another. It seems questionable whether this is simply a reflection of the different requirements for a given essential element.

In the present study, the early growth of the cotton plants does not seem to be correlated directly with the quantity of nitrogen and phosphorus in the nutrient solution, since no consistent pattern of growth performance was evident on these ionic ratios. The ratios 1-4-1, 1-1-1, and 1-2-1 are listed in order of increasing superiority for plant development (See Table 2). On the basis of these three ratios, it would seem that there was too much phosphorus in the 1-4-1 ratio and insufficient phosphorus in the 1-1-1 ratio. The plants grown on the 3-0.2-1.2 ratio were superior to the plants grown on the above-mentioned ratios, yet this nutrient solution had only one-tenth of the phosphorus present in the 1-2-1 ratio solution. Thus, although poorer growth was apparent in the 1-1-1 than in the 1-2-1 ratio, the results with the 3-0.2-1.2 ratio would indicate that this poor growth was not due to a lack of phosphorus in the 1-1-1 ratio nutrient solution.

The effect of increasing nitrogen on color of the leaves and stems was consistent, but increasing nitrogen had little influence on height growth in the 1-2-1, 2-1-2, and 3-0.2-1.2 ratios. Further investigation is required since the results may be confounded by the change in potassium as the nitrogen was increased.

It appears that the ionic ratio itself has an influence on the growth response of the cotton plant.

Summary

The ionic ratio of nitrogen, phosphorus, and potassium influenced the physiological and morphological response of young cotton plants.

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LIMNOLOGICAL STUDIES IN ARKANSAS*

II. The Effect of Intense Rainfall on the Abundance and Vertical Distribution of Plankton in Lake Fort Smith, Arkansas

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Lake Fort Smith, an artificial lake in northwestern Arkansas, constructed by inundating a mountain valley, is subject to the inflow of large quantities of water following rapid heavy rainfall. It has a surface area of approximately 525.5 acres, a volume of 525,598,000 cubic feet and a watershed covering about 6.5 square miles. The runoff water from this watershed is noticeably turbid in late winter and spring when the hills are free of green vegetation and the land is already saturated due to preceding rainfall and the slow drying of the soil during these seasons. In winter and spring large quantities of partly decayed vegetation from the previous summer and fall are carried into the lake by the runoff water.

In a study of plankton populations of Lake Fort Smith in 1939 (Hoffman and Causey, 1952) it was found that the numbers of *Kirchneriella obesa* (W. West) Schmidle virtually disappeared following intense rainfall in March and April. A similar study was made in 1949 and 1950 and special attention was given to the vertical distribution of plankton, and to the physico-chemical features occurring after heavy precipitation.

Some of the changes which rapid heavy rainfall might bring about in a lake and which in turn could influence the abundance of organisms are: increased turbidity caused by both suspended and settling materials resulting in a reduction of light and a silting down of organisms; a dilution of the organisms in the lake by large quantities being carried over the spillway; a change in the physico-chemical features which could be either harmful or beneficial to the organisms; and an addition of inorganic and organic materials which might be utilized directly or indirectly as food by the plankton.

Methods used in this investigation are discussed in Hoffman (1951) and Hoffman and Causey (1952). Samples collected in this investigation, for physico-chemical and plankton analyses, were taken at 1, 3, 5, 7, 10, 12 and 15 meters. Turbidity measurements were made with a Helige Turbidimeter.

The author is indebted to Professor Samuel Eddy of the Department of Zoology, University of Minnesota for identification of the *Peridinium* found in Lake Fort Smith; to Dr. Elbert H. Ahlstrom of the United States Fish and Wildlife Service, Scripps Institution of Oceanography, La Jolla, California for the determination of the *Dinobryon*; and to Mr. Bruce Crawford of the Arkansas Game and Fish Commission for assistance in the field.

RESULTS

The interval between May 6 and June 12, 1950 was chosen to study the effects of rapid heavy rainfall upon the abundance and vertical distribution of organisms. For the two months prior to May 6, 1950 only 0.2 of an inch of rainfall was reported in the Lake Fort Smith region, but in the 6 days previous to May 13, 1950, the second sampling date, 5.3 inches of rain fell. From May 13 through June 12, 1950 the rainfall was not heavy and the precipitation produced no evident harmful changes in the physico-chemical and biological features of the lake. The amount of rainfall in each six day period preceding each collecting date from May 19 to June 12, 1950 inclusive was as follows: May 19 (0.3 inch), May 29 (0.6 inch), June 5 (0.8 inch), and June 12 (1.3 inch). Results of this investigation are summarized in the following tables and figures: Table I gives the physico-chemical conditions; Table II and Figure 1 present the vertical distribution of turbidity, phytoplankton and zooplankton; and Table III gives

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the averaged number of plankton and the dominant forms for 1, 3, 5, 7, 10, 12 and 15 meters.

Period Preceding Intense Rainfall

An average of 453 organisms per liter, present on May 6, 1950, was the largest number of plankton encountered since November 3, 1949. Using the criterion as presented in Welch (1935, p. 48) to delimit the thermocline, the lake was stratified as of April 29, 1950. Turbidity on May 6 was low, the amount ranging from 11 to 16 parts per million. The dominant organisms present on this date were: *Dinobryon cylindricum* Imhof, *Synedra* sp., *Codonella cratera* (Leidy), and an unidentified *free swimming* zooid belonging to the order Peritricha, suborder Sessilia, tribe Aloricata. Also present, but in small numbers, were: *Trachelomonas volvocina* Ehr., *Peridinium wisconsinense* Eddy, 4 species of rotifers, a variety of members belonging to the Chlorophyta and a few individuals belonging to the crustacea. *Kirchneriella obesa*, a dominant form in the winter of 1938-1939, appeared in numbers no greater than 1 per liter in 1949-1950.

Effect of Intense Rain

During the six days preceding May 13, 1950 a rainfall of 5.3 inches fell on the lake and its watershed; on May 7 and May 11, 2.68 and 1.27 inches respectively, were recorded. This rainfall changed the transparency, as measured by the Secchi disc, from 60 centimeters on May 6 to 13 centimeters on May 13. On the latter date the turbidity also increased over that of May 6. Turbidity on May 13 ranged from 51 to 57 parts per million in the upper 12 meters (figure 1). On May 13 the turbid materials had not reached the fifteenth meter as evidenced by a low reading of 21 parts per million (figure 1). The surface temperature, following the rain, changed from 19.0°C. to 16.2°C. and the lake which was stratified the week before now showed no thermocline. Chemical changes were: increased carbon dioxide content from the surface to the bottom, a change in pH from 6.6 to 6.4 in the upper 12 meters, a lowering of the bicarbonate content, and a reduction of dissolved oxygen in the upper levels with a rise in content in the lower water levels (table I).

The phytoplankton, following this heavy precipitation, were greatly reduced in numbers from the surface through 15 meters (table II and figure 1). Of the few that occurred on this date the largest numbers were found near the surface. Since *Dinobryon cylindricum* and *Synedra* sp. were the only abundant phytoplankters collected on May 6, 1950 significant comparisons can only be made of these. Both *Dinobryon* and *Synedra* were greatly reduced when compared to the records of May 6. However, it should be indicated that the Chlorophyta, even though the numbers were not large on May 6, were completely absent on May 13 (table III).

Numbers of zooplankton following this heavy rainfall were only slightly altered. Figure 1 shows that the largest numbers of zooplankton on May 13 were found between the seventh and twelfth meters. The number occurring in the upper five meters was noticeably reduced. The averaged number of Peritricha for all meters was slightly greater on May 13 than it was on May 6 (table III). *Codonella cratera* were reduced in numbers and the rotifers, with the exception of *Synchaeta*, disappeared. Because of the small numbers of crustacea present at this time no conclusions can be drawn regarding this group.

The Recovery Period

From May 19 through June 12 the surface water lost turbidity while the lowest meters became more turbid. This probably was due to a slow settling of the temporary suspended materials. By May 19 the water had warmed and the lake was again stratified. On this date the effects of the rainfall were still evident in that the pH of the bottom had dropped from 6.6 to 6.4, the dissolved oxygen from the top to the bottom was greatly reduced and carbon dioxide showed an increase in the lower meters (table I). Following the advent of permanent stratification, May 19, the lake showed the expected changes in the chemical nature of the water: the amount of carbon dioxide was greater at the bottom than in the surface waters; pH readings were lower at the bottom than at the surface; and dissolved oxygen near the bottom was being expended.

Along with the above physico-chemical changes of the period from May 19 through June 12, 1950 the phytoplankton increased in numbers. The zooplankton numbers increased through May 29 and then began to decline. Figure 1 shows that as the water cleared in the upper levels organisms again began to concentrate here. Three of the dominant plankters of May 6, namely, *Dinobryon, Synedra* and the representative of the Peritricha were found in increased numbers again on May 19 but were virtually gone by June 12. These three forms have never been found to be abundant summer plankters in Lake Fort Smith. The other species, *Codonella cratera*, found in moderate numbers before the heavy rainfall, again increased on May 29 and occurred in small to moderate numbers throughout the summer. Along with the four forms mentioned above the general increase in numbers beginning May 29 can be attributed to species which formed the dominant plankters during the summer of 1950, such as *Sphaerocystis schroeteri* Chod., *Peridinium wisconsinense* Eddy, *Polyarthra* sp., and members of the crustacea.

DISCUSSION

From the results of this investigation and another carried on in 1939 (Hoffman and Causey, 1952) it is evident that following concentrated precipitation there is a reduction in numbers of certain types of phytoplankton in Lake Fort Smith, namely, *Dinobryon cylindricum, Synedra* sp. and *Kirchneriella obesa*. It has also been shown that a *free swimming* zooid, a member of the Peritricha, is not eliminated but is instead found in the deeper levels of the lake. This study also reveals that these Peritricha find the period after heavy precipitation in spring a favorable environment since their numbers are the greatest then.

During the six days previous to May 13 (a period of heavy precipitation) a number of environmental features were changed which independently or collectively could have reacted unfavorably on the phytoplankton. It is the author's opinion that turbidity, precipitation, and dilution were the major factors in the reduction of the phytoplankton at this time. Phytoplankters and zooplankters found on May 13 had minute particles adhering to their body surfaces which could have accounted for the transporting of the Peritricha to the lower levels and the phytoplankton to the bottom of the basin. If this conclusion is correct then the survival of the Peritricha might be explained in their swimming ability in contrast to that of the phytoplankton. If the phytoplankters were carried down by settling materials one would expect to find them at the lower level of the turbid water. In studying Lake Fort Smith, from time to time, over a period of 13 years the author has found that a sample taken a day or two after heavy rainfall does not reveal the true nature of all the material washed into the lake. A sample taken directly after rainfall will often have fragments of shale, limonite and quartz grains large enough that each particle can be distinguished with the naked eye. If a sample is taken a day or two after a heavy precipitation these larger particles have found their way to the bottom and only the slow settling and suspended materials remain to produce the turbidity of the water. It is possible that these larger particles, found directly after rainfall, carry quantities of phytoplankton down with them and in this way reduce the numbers soon after the turbid materials enter the lake. Another factor in relation to turbidity to be considered which evidently plays an important role is the reduction of light, which interferes with photosynthesis and eventually eliminates the phytoplankter. A number of other investigators (e.g., Chandler, 1940, 1942; Verduin, 1951) have found turbidity a limiting factor to phytoplankton numbers.

Five inches of rain falling over a watershed of 65 square miles and flowing into a lake with a surface area of 525.5 acres will add large quantities of water to the lake. One important factor to be considered here is that not all of the precipitation on the watershed in May 1950 reached the lake, and as the rainfall was spread over a period of six days, all of the runoff water did not reach the lake at once. Since it is the water near the surface of the lake which flows over the spillway it can be assumed that phytoplankters which are concentrated in the upper levels continue to move toward the spillway as long as washing currents carry them; this could also explain the reduction of Peritricha in the upper meters at this time. It therefore appears that each liter of water that passes over the spillway carries plankters with it, but this does not

entirely account for the rapid reduction of phytoplankton in the lower levels following heavy rainfall.

The total number of Peritricha for all meters on May 13 was slightly greater than the total for the same meters on May 6. The Peritricha present in the deeper levels on May 6 may have found the conditions in the lower levels from May 6 to May 13 very favorable and increased in numbers while those in the upper levels were carried over the spillway. But, the adherence of foreign materials to the bodies of these Peritricha strongly suggests that many were carried down to the lower levels. In conclusion, it appears that three major factors in Lake Fort Smith following rainfall which influence the productivity and distribution of plankters are: (1) a sinking or settling of materials carrying organisms to the deeper levels, (2) turbidity with a reduction of light, and (3) a dilution of the water in the upper meters by water coming in from the watershed and flowing over the spillway.

Other factors which may have contributed to the reduction in numbers of phytoplankton are the lowering of temperature and the change in hydrogen-ion concentration. Since both carbon dioxide and dissolved oxygen are used in the life processes of these organisms, and since neither was changed to extremes, it is difficult to comprehend how these could be major factors here. *Dinobryon* could have been influenced by the sudden temperature change because it was not found in numbers in the winter plankton of Lake Fort Smith and it had just made its appearance, at a higher temperature, on May 6. *Synedra* sp., although never found in large numbers in Lake Fort Smith, appears throughout the winter and is probably not influenced by a lowering of temperature alone.

A study of the data presented in this report reveals that it is necessary to take plankton samples from the deeper levels in Lake Fort Smith in order to obtain a reliable estimation of the zooplankton present in spring. Collections taken during this investigation from the first five meters give a relatively accurate measurement of the phytoplankton but give an erroneous picture of zooplankton abundance. Table III shows that the average number of zooplankton for all meters does not differ greatly between May 6 and May 13, 1950; however, table II and figure 1 show that these zooplankton were found in the deeper levels on May 13.

SUMMARY

1. Lake Fort Smith, Arkansas, with a watershed of 65 square miles and a lake surface area of 525.5 acres, has large quantities of turbid water flowing into it following rapid heavy rainfall in late winter and spring.
2. This investigation deals with the period from May 6 through June 12, 1950. In the two months previous to May 6 only 0.2 inches of rainfall was reported while in the 6 days previous to May 13, 5.3 inches fell.
3. Rainfall, in the 6 days prior to May 13, brought about the following physico-chemical changes: reduced transparency, as measured by the Secchi disc; increased turbidity down through the twelfth meter; lowered water temperature and disturbed stratification; increased carbon dioxide content from the surface to the bottom; lowered pH in the upper twelve meters; lessened bicarbonate content; and reduced dissolved oxygen content in the upper meters.
4. Organisms found in significant numbers on May 6, just before the heavy rainfall, were: *Dinobryon cylindricum* Imhof, *Synedra* sp., *Codonella cratera* (Leidy) and a *free swimming* zooid belonging to the order Peritricha, suborder Sessilia, tribe Aloricata.
5. On May 13, after the heavy rainfall, the numbers of phytoplankton were reduced from the surface to the bottom. Zooplankters were concentrated in the 7 to 12 meter level and reduced in the surface waters. The total number of Peritricha present on May 13 was slightly greater than on May 6.
6. In the period after May 13, as the surface water cleared, organisms again appeared here. The Peritricha reached their highest numbers for the year during the last two weeks in May.
7. In Lake Fort Smith turbidity, precipitation, and dilution, following rapid heavy rainfall, appear to be major factors in the reduction of Phytoplankton.

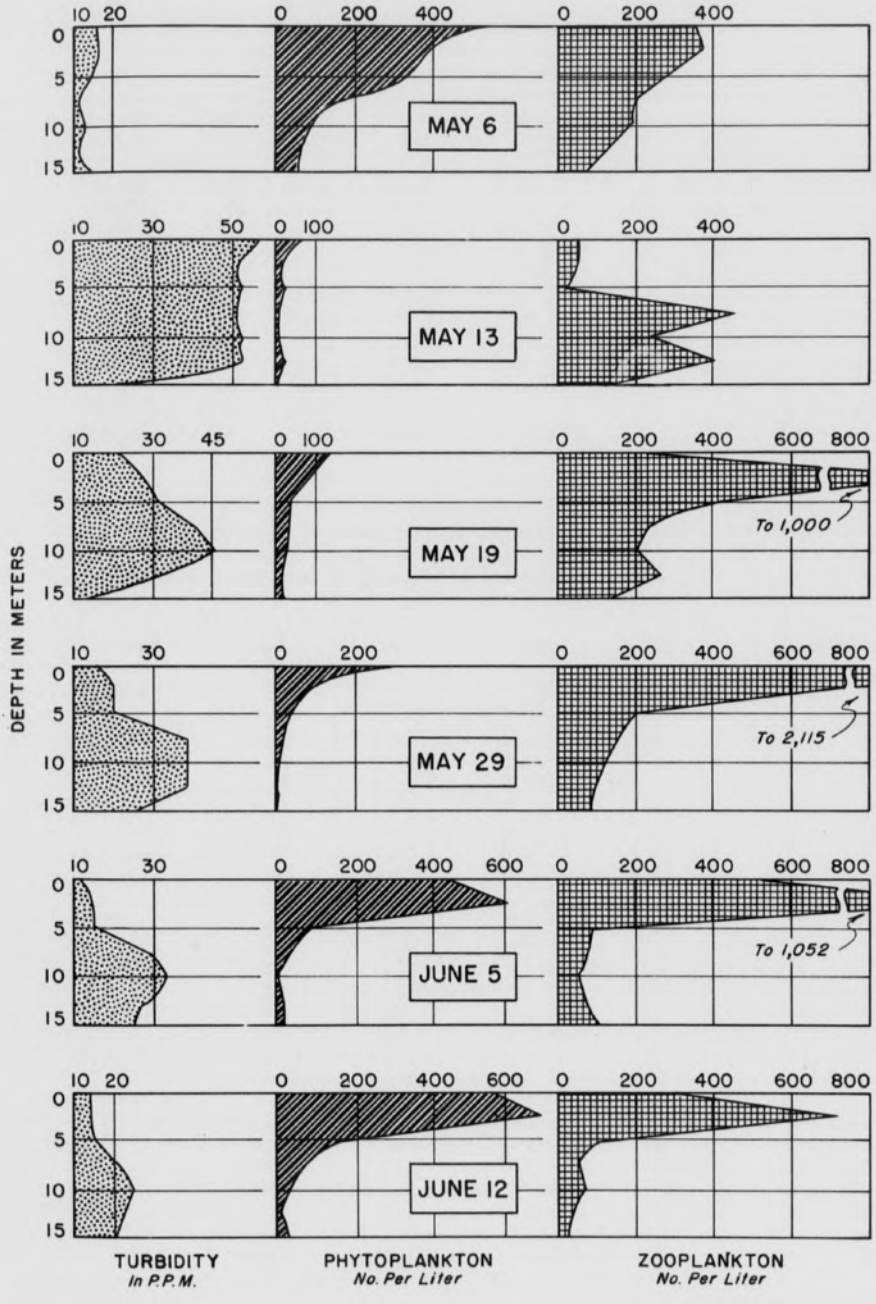

Figure 1. A graphic representation of the vertical distribution of turbidity, phytoplankton and zooplankton from May 6 through June 12, 1950 in Lake Fort Smith, Arkansas. May 6 shows the normal spring vertical distribution, May 13 shows the effects of 5.3 inches of rainfall, and the period from May 19 through June 12 shows the recovery period.

TABLE I. Summary of Some Physico-Chemical Conditions in Lake Fort Smith, Arkansas, from May 6 through June 12, 1950.

	May 6	May* 13	May 19	May 29	June 5	June 12
Transparency in cm.	60.0	13.0	30.0	59.0	68.0	80.0
Surface Temp. in °C.	19.0	16.2	20.4	22.6	22.8	26.8
Stratified	yes	no	yes	yes	yes	yes
Bottom Temp. in °C.	12.0	12.1	12.2	11.2	12.4	12.4
Surface CO_2 in ppm.	2.5	5.0	2.5	2.0	2.0	2.0
Bottom CO_2 in ppm.	2.5	3.0	4.0	6.0	5.0	5.0
Surface M.O. Alk. in ppm.	20.0	11.0	16.0	17.0	19.0	23.0
Bottom M.O. Alk. in ppm.	18.0	11.0	15.0	17.0	19.0	23.0
Surface O_2 in ppm.	9.0	8.4	6.8	8.6	7.8	7.0
Bottom O_2 in ppm.	6.6	8.2	6.6	5.8	5.0	4.3
Surface pH	6.6	6.4	6.6	6.7	7.2	7.2
Bottom pH	6.6	6.6	6.4	6.4	6.6	6.6

*Following intense rainfall

TABLE II. Vertical Distribution of Turbidity, Phytoplankton and Zooplankton in Lake Fort Smith, Arkansas, from May 6 through June 12, 1950.

Meters	May 6	May* 13	May 19	May 29	June 5	June 12
			Turbidity in PPM.			
1.	16.0	57.0	21.0	15.0	11.0	14.0
3.	16.0	52.0	29.0	20.0	15.0	14.0
5.	15.0	52.0	31.0	20.0	15.0	14.5
7.	11.0	51.0	41.0	38.0	29.0	20.5
10.	12.0	52.0	46.0	38.0	33.0	24.5
12.	11.0	52.0	36.0	38.0	28.0	22.5
15.	15.0	21.0	15.0	26.0	25.0	20.5
			Phytoplankton in Organisms per Liter			
1.	535	54	132	290	442	560
3.	375	7	75	75	605	692
5.	350	7	35	37	77	180
7.	172	2	27	20	35	60
10.	80	5	30	5	12	27
12.	60	7	17	5	17	7
15.	45	2	20	2	17	22
			Zooplankton in Organisms per Liter			
1.	345	45	185	2115	510	250
3.	355	52	987	717	1052	712
5.	282	22	452	197	87	110
7.	200	447	242	160	75	50
10.	192	232	212	130	62	57
12.	117	402	270	100	70	27
15.	67	157	147	87	102	25

*Following intense rainfall

TABLE III. Averaged Number of Net Plankters Per Liter for 1, 3, 5, 7, 10, 12 and 15 Meters in Lake Fort Smith, Arkansas, from May 6 through June 12, 1950.

Groups and Plankters	May 6	May* 13	May 19	May 29	June 5	June 12
All Chlorophyta	15	0	1	5	17	36
All Euglenophyta	7	2	9	7	3	13
Dinobryon	94	3	16	36	19	1
Mallomonas	2	0	0	0	109	128
Other Chrysophyceae	0	0	0	0	0	0
Synedra	100	6	17	3	1	1
Other Bacillariophyceae	6	0	2	3	1	16
Peridinium	7	1	0	7	20	26
Other Pyrrophyta	0	0	0	1	2	0
Total Phytoplankton	231	12	45	62	172	221
Codonella	20	5	7	22	5	15
Peritricha	177	185	323	355	30	6
Other Protozoa	0	0	0	0	0	0
Conochilus	7	0	1	2	16	100
Keratella	3	0	0	1	3	1
Polyarthra	6	0	0	85	180	29
Synchaeta	3	1	1	27	3	1
Other Rotifera	0	0	0	2	2	7
Daphnia	1	1	1	0	12	1
Other Cladocera	2	0	0	3	6	0
Nauplii	2	2	0	3	19	11
Other Copepoda	1	0	0	1	4	4
Total Zooplankton	222	194	333	501	280	175
Total Plankton	453	206	378	563	452	396

*Following intense rainfall

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ADDITIONAL NEW RECORDS FOR THE ARKANSAS FLORA, II*[1]

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While the flora of Arkansas has been studied to a certain extent for over 130 years the study has not been complete nor thorough in many respects. A few areas have been fairly well worked out but new taxa are continually showing up in nearly all parts of the state. The following represent a few new records made during the year, 1950-51.

1.) *Sisyrinchium Brownei* Small. A small species reported in Small's Manual of the Southeastern Flora (1) in "low swampy ground, coastal plain, S.E. Louisiana", was found along the roadside and adjacent meadows in southern Arkansas below El Dorado in April 1950.(2) The following year, April 1951, this was again located in several other stations in the same county but along with which another species 2.) of *Sisyrinchium* with flowers that appeared at a distance to be pale blue or lavender. Closer inspection showed that the perianth was really white with lavender lines through the center and around the edges. Up to the present, the identity of this plant has not been satisfactorily determined. (Dr. Clair A. Browne of Louisiana State University thinks it is a hybrid between *S. Brownei* and another blue species.)

3.) For several years plants which appeared to be *Iris verna* L. have been observed in the region of Bauxite in south central Arkansas but no flowering material had previously been found, until specimens were taken in Polk County in April, 1950, by Miss Aileen McWilliam of Mena. On April 1, 1951, flowering specimens of this species (or its variety *Smalliana* Fern.) were found in the Ouachita Mts. in Polk County and in the Bauxite region of Saline County confirming previous observations. This is a marked westward extension for this species beyond previously reported occurrence.

4.) *Pogonia ophioglossoides* (L.) Ker. was found for the first time in the state, in Ferguson Lake, northern Saline County, growing on floating logs which were well provided with other vegetation. Included with it was the southern 5.) *Habenaria quinqueseta* (Michx.) Sw. which was also a new record for this locality. It might be noted that this latter species shows a strong honey-like fragrance at night but no odor at all during the day. It has previously been reported only from Grassy Lake in Hempstead County.(2)

6.) At this same place were found some 30 inch-tall specimens of *Calopogon pulchellus* (Salisb.) R. Br. This species is quite common in our wet meadows and prairies but seldom grows more than 10 or 12 inches tall. These specimens, two or three times that size, were quite surprising although reference to the new Gray's Manual(3) discloses that the species ranges from "0.7 (northw.) -9.75 (southw.) dm. high". Perhaps these will bear further study since shorter ones have been collected farther south in Arkansas than these tall specimens taken at Ferguson Lake.

7.) *Dianthus prolifer* L., a European visitor, was found for the first time in Fulton County in June 1951. The first of these were found in the mixed sand and gravel margin of Myatt Creek about 8 miles south of Mammoth Spring. Later more of it was found on a limestone glade some 5 miles farther southwest.

8.) *Parnassia grandifolia* DC., which grows commonly in Missouri to the north and in other states adjacent to Arkansas, was seen for the first time in Stone County, June '51. It was not in flower, but remnants of last seasons flower stalks and bracts helped in the identification. Specimens taken to the writer's garden bloomed in October.

9.) *Oenothera Spachiana* T. & G., a southern representative of this genus, was found near White Cliffs in Sevier County, May 4, '51.

*Research Paper No. 1032. Journal Series, University of Arkansas.

[1]Paper presented before the joint meeting of the Amer. Soc. of Plant Taxonomists and the Systematic Section of the Bot. Soc. of America; Minneapolis, Sept. 11, 1951.

10.) *Euonymus obovatus* Nutt. was also observed in Stone County in June 1951.

11.) One of the most unusual additions to the flora of Arkansas and probably that of the U. S. was found in southern Fulton County in June '51. The specimen found could not be identified by reference to any American manual but reference to Hegi's Flora of Central Europe[4] disclosed its identity as *Sideritis montana* L. This member of the Labiatae has the general appearance of a robust specimen of *Hedeoma hispida* but each calyx lobe is terminated by a sharp spine about two millimeters long. The whole plant is noticeably hairy and the small flowers are yellow, tipped with red brown to deep brown color. Dr. Julian A. Steyermark has confirmed this identification. Inquiry of the other large herbaria has disclosed no other specimens of this species from out of cultivation in the U. S.

12.) For several years we have been observing quantities of a white flowered *Houstonia* in the southern part of the state. From material submitted to Dr. Steyermark he reports that this is a previously underscribed variety of *Houstonia minima*. However, certain features suggest that it may be distinct. This will be officially named and published shortly.

13.) Another southern species to show up along the southern border of Arkansas is the little composite *Facelis apiculata* Cass. This had been observed in the vegetative stage for a period of several years but eluded identification until the spring of '51 when flowering material rendered its identification possible.

14.) Still another very unusual find was *Sporobolus pulvinatus* Swallen, a small member of this genus found on a "salt flat" about two miles north of Charleston, Franklin County. This was picked up by Mr. Marvin A. Lawson, of the Soil Conservation Service while making a special study of the vegetation of certain soil types in Arkansas. The most unusual consideration about this specimen is that previously it was known only from Texas, New Mexico, and Arizona. As Dr. J. R. Swallen, curator of the National Herbarium says, "This is a very great extension of range, as we have not had any specimens from so far east."

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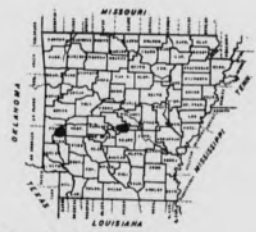
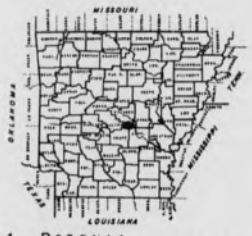
4. Hegi, Gustav, Illustrierta Flora von Mitteleuropa.

1. SISYRINCHIUM BROWNEI

2. SISYRINCHIUM ?

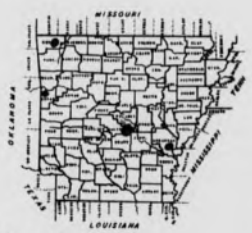


3. IRIS VERNA



4. POGONIA OPHIOGLOSSOIDES

5. HABENARIA QUINQUESETA

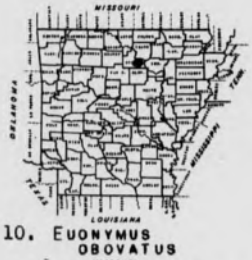


6. CALOPOGON PULCHELLUS

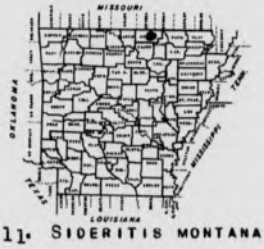
7. DIANTHUS PROLIFER

8. PARNASSIA GRANDIFOLIA

9. OENOTHERA SPACHIANA

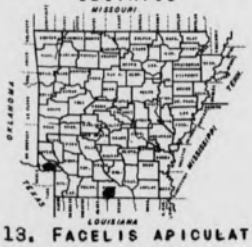


10. EUONYMUS OBOVATUS

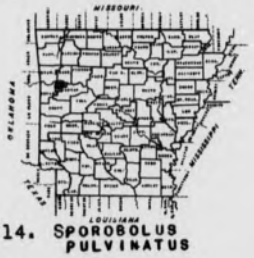


11. SIDERITIS MONTANA

12. HOUSTONIA ?



13. FACELIS APICULATA



14. SPOROBOLUS PULVINATUS

THE PREPARATION OF SERICEA PAPER PULP

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Introduction

The consumption of paper per capita in a country is a good measure of the prosperity and economic development of that country. In the United States the per capita consumption of paper was about 380 pounds in 1950, about 15 times the world average. The production of paper and paperboard in this country has increased rapidly since 1932. During this period the total production increased by more than three times to an all-time record of 24.3 million tons of paper and paperboard in 1950. This rapid increase in production has naturally caused a strain on the supply of wood for paper-making, since about 10% more wood is cut each year in the United States than is grown.

Just where do agricultural residues fit into the paper industry? As the supply of timber decreases, the importance of fibrous raw materials from agricultural residues is becoming more important. In addition to aiding the conservation program, these pulps lend their special characteristics to producing paper products of a desirable quality. Some examples of this are the production of high grade insulating board from sugar cane bagasse, of cigarette paper from flax straw, of thin books and bible paper from esparto, and of corrugated paperboard from wheat straw. Pulps from agricultural residues are also blended with conventional stock to develop properties not attainable by the use of a single pulp. This blending of pulps to improve such properties as uniformity, smoothness, opacity, printing speed, and strength of paper will assume greater importance in the future.

Paper Making Processes

The four major processes for producing pulp are the groundwood process, the sulphite process, the soda process, and the sulphate or kraft process. The groundwood process is a mechanical process whereby blocks of wood are ground into pulp by forcing them against revolving stones. This pulp is used mostly in newspapers and low grade magazine and wrapping paper.

In the sulphite process the wood chips are digested with an acid liquor containing calcium bisulphite at a high temperature and pressure. Because of its ease of bleaching this pulp is used mostly in writing and printing papers. The soda process employs a solution of sodium hydroxide to remove the lignin binder from wood. This process may be used for many types of wood that cannot readily be treated by the sulphite process. Soda pulp is used largely in wrapping paper, magazine and book papers.

The sulfate process, which is also known as the kraft process, is a modification of the soda process. The two active chemicals in the digesting liquors are sodium hydroxide and sodium sulphide. The addition of sodium sulphide results in higher yields and stronger pulps than either of the other two chemical processes. However, the pulp made by this process is a dull brown color and for a long time was considered to be unbleachable. About twenty years ago a multistage bleaching process was developed for bleaching sulfate pulp to almost any desired degree of whiteness. Today this process is by far the most important one, and nearly all of the pulp mills which have been built recently are of this type. Almost any type of wood may be pulped by the sulphate process and the pulp has a wide range of uses from corrugated packing containers to fine writing paper. For the reasons just stated, the sulphate process was used for pulping lespedeza in the experiments carried out in the Chemical Engineering Department at the University of Arkansas during the past three (3) years.

Lespedeza sericea, which is commonly called sericea, produces a dense, woody stalk which is similar to hardwood. The stalk of this plant, when mature, is about one-quarter inch in diameter and four or five feet tall. Pulping the stalks to produce three different types of pulp was carried out in the work reported here with special emphasis on papermaking pulp. The stalks were first

run through a set of steel crushing rolls to crack them. The purpose of this treatment was to allow better penetration of the cooking liquour into the wood. The stalks were then cut into two inch lengths on a band saw and blown with compressed air to remove dust and dirt. The chips were then ready for digestion.

The five independent variables in the sulphate process are (1) ratio of active alkali to wood, (2) sulphidity, (3) concentration of active alkali, (4) cooking temperature, and (5) time of cooking. Active alkali is defined as the weight of sodium hydroxide plus the weight of sodium sulphide, with both quantities expressed as the equivalent weight of sodium oxide. The percentage of active alkali is based on the dry weight of chips. Sulphidity is defined as the ratio of sodium sulphide to sodium hydroxide plus sodium sulphide, with all quantities calculated as sodium oxide equivalent weights.

Wallboard Pulp

The conditions of cooking are greatly influenced by the use for which the pulp is intended. The three uses for sericea pulp which have been investigated are wallboard pulp, paper pulp and dissolving pulp for making cellulose derivatives. Pulp for wallboard does not require the elimination of lignin that is needed for paper pulp. Therefore the sericea that was used for this purpose was digested under relatively mild cooking conditions. The chips were only partially delignified, since the residual lignin helped to serve as a plastic binder when boards were formed under heat and pressure. When sericea was digested with these mild cooking conditions, long strands from the fibrous bark skin remained in the pulp and also contributed to greater strength in the boards. The optimum cooking conditions for making wallboard pulp were five per cent active alkali, fifteen per cent sulphidity, fifteen grams per liter of active alkali and two hours cooking at a temperature of 325 degrees Fahrenheit. Yields of about seventy per cent were obtained, calculated on a dry basis. After the pulp was removed from the digestor, it was washed for thirty minutes in a centrifuge with a continuous stream of hot water, then defiberized by running through a Bauer mill with one stationary disc and one revolving disc. Wallboards of excellent quality were formed from this type of sericea pulp by appropriate methods.

Paper Pulp

A better pulp with much less lignin on the cellulose fibers is required for papermaking than for making wallboard. It was therefore necessary to cook the chips more strongly so that the fibers could be more completely separated. The bark skin was broken down into individual fibers under the stronger conditions. The cooking conditions were changed in different runs to determine the effects of each of the variables. After the pulp was washed and refined, it was made into paper on the laboratory sheet mold and tested to determine the physical strength properties. The approximate cooking conditions used for making paper pulp from sericea were the following: 20 per cent active alkali, thirty per cent sulphidity 35 grams per liter of active alkali, and 3½ hours at a temperature of 350 degrees Fahrenheit. The average yield of pulp was about forty-five per cent, dry weight basis. The papers made from this pulp had excellent tensile and bursting strengths, but were relatively low in tearing and folding strength. The reason for this is that the average fiber length of sericea is only about six-tenths of a millimeter, which is much shorter than fiber from pine or spruce woods. However, the shortness of the fibers contributes to greater uniformity and smoothness. The tearing and folding strength properties may be increased by blending sericea pulp with about 20% of a longer fibered pulp, such as sulphate pine pulp.

Dissolving Pulp

Pulp which is to be used to make cellulose derivatives requires a high percentage of alpha cellulose, and the ash content must be kept as low as possible. The chips used in making this pulp were carefully cleaned before pulping. They were pulped more strongly in order to get a more complete removal of lignin. The average cooking conditions for this type of pulp were the following: 26 per cent active alkali, 35 grams per liter of active alkali, 30 per cent sulphidity, and three and a half hours at a temperature of 350 degrees fahren-

heit. This pulp was washed as before and bleached in three stages. The bleaching process developed consisted of treating with chlorine water, extraction with dilute sodium hydroxide, and finally bleaching with chlorine dioxide solution. The complete details and specifications for producing a dissolving pulp will be worked out by other investigators, since this research was directed at paper pulp production.

Conclusion

Sericea may well be the source of pulp for expanded cellulose industries in Arkansas and other southern states; but further technical development and economic studies are needed to determine the real importance of Lespedeza Sericea as a source of paper pulp.

METHODS AND PROBLEMS IN THE MEASUREMENT OF ECONOMIC CHANGES IN STATES*

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I

This paper will deal primarily with methods and problems of measurement of economic change within a state of the United States of America. However, it will go into the details of only one of the measures of economic change, the measurement of income produced in Arkansas by industrial origin. This topic will be taken up in the second part of this paper.

Two of the other basic measures or indicators of long-run economic change within a given area are data on the number of persons gainfully employed, and the percentage employed in each particular industry. W. Paul Brann, Bureau of Business Research, University of Arkansas, has prepared estimates of these measures for census years from 1910 to 1940. They will be extended forward to 1950 and backward to at least 1880.

The two measures, income by industrial origin and the percentage of persons employed by industry, provide a clear picture of the economic structure of a state at given moments in time. New theoretical tools--or at least new uses of old tools--and additional data sought out on the basis of these tools are required if we are to follow the processes of economic change and gain further insight into their causes.

One familiar tool is the measurement of physical productivity. Several excellent studies of changes in agricultural productivity for this area are available. A new method in macroeconomic analysis is the statement of sources and uses of funds. V. Q. Alvis has made the first local efforts toward developing such a statement for Arkansas. He is also working on the application of the balance of payments concept to interstate trade, another hopeful development.

Thought must also be given to the development of the terms of trade for Arkansas. This concept has been used to advantage by Colin Clark, the Australian statistician, in his studies of economic progress. The "terms of trade" simply refers to the prices at which a country (region) buys as compared to those at which it sells. What determines the terms of trade? It is certainly evident that the list of elements important in the determination of the terms of trade between countries would be considerably different from those that are important in determining the terms of trade between an area such as Arkansas and the rest of the United States. It is probable that the relative importance of the items which appear on both lists differ. Werner Hochwald of Washington University has emphasized that the "export" industry or industries of a region are strategic in that region's economy. May I suggest that if the income elasticity of demand for this "export" is low, if pure competition prevails in this industry, and if productivity is increasing, the terms of trade will probably be running strongly against this region.

All of these--the percentage of gainfully employed by industry, changes in physical productivity, sources and uses of funds, balance of payments, and terms of trade--should be helpful in the formulation of a complete statement of the causes and processes of economic change in a given region.

II

Estimates of income in each state of our country by industrial origin have been made by the Department of Commerce since 1929. Maurice Leven of the National Bureau of Economic Research has constructed estimates of income in the various states for 1919, 1920, and 1921. The Department of Commerce estimates for the United States as a whole start in 1929, but those of the National Bureau of Economic Research go back to 1909.

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One object of my research is the construction of estimates of the net income of Arkansas industries from 1909 to 1929. This will provide a series of income estimates which can be spliced to adjusted Department of Commerce estimates to provide a continuous series from 1909. Such a series will be a valuable aid in studying changes in the structure of the Arkansas economy.

Before reviewing the methods used by the Department of Commerce and the National Bureau of Economic Research, and the content of their estimates, I will define the principal concepts, show the relationship between these concepts, and demonstrate that the aggregate net income--*i.e.*, the earnings of the factors of production which arise from the current production of goods and services--can be estimated in two ways.

We can start either by adding the earnings of the productive factors employed in an industry, or with the sales of an industry. Let us start with the largest aggregate--sales. For example, data for the total sales of the manufacturing industries are available in the Census of Manufactures. The term used in the census for sales is "value of products." This is defined as "the selling value, at factory, of all products shipped or delivered." In the manufacturing industries, however, these sales include large elements of duplication because of sales between firms in different manufacturing industries. Interfirm sales must be deducted to arrive at value added by manufacturing. The items deducted in the Census from value of products to leave value added are: cost of materials, supplies, containers, fuel, and purchased electric energy. Value added is greater than net income because this list omits several important expenses, other than factor payments, such as capital consumption allowances, insurance, rent, selling expenses, and indirect business tax and nontax payments. If we could deduct the items just mentioned from value added the remainder would be net income from manufacturing.

This aggregate, net income, can in no way be estimated from Census information alone. Nevertheless, there is no conceptual barrier to stating the relationship between value added, as defined by the Bureau of the Census, and net income. If all expenses, except factor earnings, which were not previously deducted in calculating value added are now deducted from value added, the remainder is net income. Incidentally, once all of the expense items which are deducted from value of product to arrive at net income are known and the physical quantities of each item purchased are also known, we have the basis for the type of "input-output" analysis being developed by Wassily Leontief of Harvard.

The Department of Commerce and the National Bureau of Economic Research built up net income in each industry by adding the earnings of the factors of production which arise from the current production of goods and services. The items added by the National Bureau are: wages, salaries, entrepreneurial withdrawals, dividends, interest, entrepreneurial income, net savings of entrepreneurs, and net savings of corporations. The procedures of the National Bureau and the Department of Commerce are similar. Detailed statements of the procedures of both agencies have been published.[1]

The components of factor income for each industry, when added, give the net income for the industry. The "difference" between net income and value added can be easily calculated by subtracting net income from value added.[2] When this "difference" is added to net income along with the other expenses enumerated by the Bureau of Census, the sum is value of product. The following table summarizes the relations which have been stated:

[1]The description of the procedures, methods, and terminology of the Department of Commerce is published in the *National Income Supplement to the Survey of Current Business*, (Bureau of Foreign and Domestic Commerce, United States Department of Commerce, July 1947); that of the National Bureau is found in Simon Kuznets', *National Income and its Composition*, 1919-1938, 2 Vols., (National Bureau of Economic Research, 1941) The latter contains an extended treatment of the theoretical and practical problems involved in the construction and interpretation of National Income and its components.

[2]It should be noted that these two aggregates are independently determined.

Read Down	VALUE OF PRODUCT	Read Up =
-	Cost of materials, supplies, containers, fuel, and purchased electric energy	+
=	VALUE ADDED	=
-	Such items as capital consumption allowances, insurance, rent, selling expenses, and indirect business tax and nontax payments	+
=	NET INCOME	=
	Wages	+
	Salaries	+
	Dividends	+
	Interest, etc.	+

The net income of each industry in the United States has been estimated by the National Bureau for the period 1909-1938. State income estimates are not available before 1929 except for 1919, 1920, and 1921 as stated above. The value added by manufacturing is available for 1909, 1914, 1919, and every second year thereafter to 1939 for both the United States and Arkansas. On the basis of the value added in manufacturing in Arkansas it is possible to construct estimates of net income from manufactures for the state for census years.

In preparing estimates of net income from manufactures in Arkansas the following procedure was used. The relationship between net income (National Bureau) and value added (Census)--which aggregates, it will be recalled, come from independent sources--proved to be stable when tested for the United States. It was then assumed that the relationship between net income and value added in Arkansas would also be stable. However, the percentage relationship between net income and value added in Arkansas is not the same as it is for the United States because of local differences in various costs. The Department of Commerce estimates of income[3] from manufactures in Arkansas and the United States were calculated as percentages of the corresponding value added in manufacturing. This calculation indicated that income from manufactures in Arkansas as a percentage of value added was on the average almost three per cent higher than the corresponding figure for the United States. The percentage relationship between net income from manufactures and value added by manufacturing for the United States for 1929 and prior census years back to 1909 was adjusted on this basis in order to have an estimated relationship for Arkansas for years in which no estimate of net income is available. This estimated relationship for Arkansas was then applied to value added from manufacturing in Arkansas for the corresponding census years in order to estimate net income from manufacturing in Arkansas back to 1909.

The precedure for estimating net income in the other industries, with the exception of agriculture, is similar. It may be possible, however, to estimate net income from manufacturing and the other industries in Arkansas by adding factor earnings. This is essentially the method used by the Department of Commerce for estimating income by industrial origin by states for the period 1929-1949. However, several types of data, such as those given in the *Statistics of*

[3]The Department of Commerce estimates of income in the various industries in Arkansas consist of: wages and salaries, entrepreneurial income, property income, and other income. Other income includes public assistance, veterans' pensions, social insurance benefits, and other government transfer payments. Property income includes dividends, interest, net rents and royalties. Income received (Department of Commerce) is not identical with net income for various reasons such as: (1) property income is shown on a "where received" basis; (2) other income is composed largely of transfer payments which are not a part of net income; (3) corporate profits before income taxes are not included in the Department of Commerce income series. However, wages and salaries, and entrepreneurial income are included in both concepts and comprise the bulk of both income received and net income.

Income, published by the Bureau of Internal Revenue, are not available for the individual states. Futhermore, the National Bureau of Economic Research employed a staff of workers for several years in preparing its estimates. Such an undertaking for a state is obviously beyond the capacity of any individual. Even if it were undertaken its success would be doubtful.

The method of estimating income suggested in this paper has several advantages. First, estimates can be made with limited resources; second, these estimates are sufficiently accurate for the purpose of revealing the important changes in the economy of a state in so far as this is possible for income statistics; third, precautions are taken to insure that secular changes, cyclical fluctuations, and cost structures peculiar to an area are not removed; fourth, these estimates may be readily compared with estimates of the United States, or for other states, when such estimates are made.

For agriculture, detailed estimates of income from both home consumption and cash sales, and expenses, can be made for each year back to 1909. A study made by the Department of Agriculture to supply data for the purchasing power parity concept contains complete details for agricultural income back to 1924. The coverage for the years 1909-1923 is about 75 per cent complete--that is, about 75 per cent of the farm income in Arkansas has been estimated by the United States Department of Agriculture. My estimates for the remainder of farm income are now being prepared and will be completed within a few weeks. It is hoped that estimates of net income for all the industries in Arkansas from 1909-1929 will be completed by next fall.

SOME PROBLEMS IN THE CONSTRUCTION OF A BALANCE OF PAYMENTS FOR AN INTRANATIONAL REGION*

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Historically, economic writings and thought have been concerned, in their spatial aspects, largely with national states as the unit for study.[1] During the period in which economics is usually thought of as becoming a distinct discipline, interest was centered around the relationships between nations, and nations were dealt with as economically homogeneous entities. Commercial and financial contacts with other nations were usually treated as being either beneficial or harmful to the national political unit, and all parts of the nation were helped or hindered simultaneously and in the same direction by any given economic phenomenon. That various geographic segments of the larger whole might react in a markedly different manner to a given stimulus was not treated as being of particular interest or importance.

Although a large body of writings grew up around the topic of international trade at an early date and has continued to expand to the present, it is only in comparatively recent times that there has occurred within the field of economics a widespread interest in the interregional relationships of small areas contained within a single national political entity. Exceptions to this generalization are few, and these few are pretty largely not the work of English-speaking writers.[2] This does not mean to imply that the principles of international and interregional economic relationships exist in unrelated and unconnected compartments. Much, if not all, of the body of analysis applicable to one of these fields is applicable to the other.[3] The difference between the two situations stems largely from the more intimate and informal nature of the contacts in the case of intranational regions as well as a tendency toward less diversity within a small region---principally a difference of degree.

In attempts to understand and explain international and interregional economic relationships, the process of deduction has been employed quite generally. A great quantity of rigorously consistent analysis exists in the field of international economic relationships. Much statistical material has been compiled in this field also, but it is generally better suited for descriptive purposes than for the demonstration of causal relationships. Attempts to employ empirical material to substantiate deductive conclusions have been relatively infrequent in international economics. And of still less frequent occurrence are empirical studies of economic relationships between regions located within a single political boundary.[4] The studies of this latter type which have been made have centered largely in the investigation of a specialized problem or comparison of static quantities, rather than in the establishment of the functional structure of interregional relationships. Only recently have there been concerted efforts to carry through such studies, and the existing studies of this type leave something to be desired in both completeness and comprehensiveness. The empirical data concerned with international economic phenomena are inadequate for many purposes, but material directly relevant to interregional phenomena of small areas is largely non-existent. Attempts to analyze such data as do exist are

[1]See for example, Viner, Jacob, *Studies in the Theory of International Trade*, Harper, New York, 1937, p. 599.

[2]On this point see, Predohl, Andreas, "The theory of Location in its Relation to General Economics", *Journal of Political Economy*, Vol. XXXVI, (June 1928), pp. 371-390.

[3]See Iversen, Carl, *Aspects of the Theory of International Capital Movements*, Oxford University Press, London, 1935, p. 3; Oblin, Bertil, *Interregional and International Trade*, Harvard University Press, Cambridge, 1933, p. 230.

[4]Neff, Philip, "Interregional Cyclical Differentials: Causes, Measurement, and Significance," *The American Economic Review*, Vol. XXXIX, No. 3, May 1949, pp. 106-7.

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valuable not only because they help fill in, however imperfectly, complete gaps in knowledge, but also because they point out the nature of the additional information necessary in order to fill up the gaps completely.

The spatial entities considered in a study of international economic relationships are predetermined on political grounds. In the matter of interregional relationships, the units dealt with may be variously defined. The obvious precedure is to choose regions which, from some viewpoint, contain comparatively little economic diversification. While on the surface this may appear to be an easy solution, such a generalization has solved very little if any of the practical problems involved. The question immediately arises as to the aspects in which uniformity is to be sought. It may be on the basis of the pattern of trade relationships within the area, either at the wholesale or retail level, the nature of products exported to or imported from other regions, the structure of total production and employment, the pattern of money flows, etc. Of course, if availability of data were complete, the spatial units chosen in any single instance would depend primarily upon the objective of the study. Areas of unvarying composition from the peculiar point of view of the problem at hand would be selected as the most appropriate units to treat. But in light of the present state of statistical information applicable to small intranational regions, it is of questionable value to pursue further a delineation of the ideal method of approach. At the moment, it is necessary to temper the abstract ideal with expediency.

Statistical data concerned with intranational economics, as in the case of international economics, are compartmentalized almost wholly along the lines of political divisions. Thus it becomes necessary, if existing statistical data are to be used, to consider political units as economic units and this practice is followed here. Once this compromise with strictly rational procedure is made, there remains to be decided the political division to be used as an economic unit. The smaller the political division chosen, the smaller in general is the quantity of available data; but the smaller the area involved, the more likely it is to have some semblance of internal consistency. On the basis of data availability alone, an area made up of several states would appear to be the logical entity with which to deal. Yet certain phenomena can be meaningfully treated only as they apply to more restricted areas, and consideration of somewhat smaller units is a first step in the direction of using strictly homogeneous areas as economic units for investigation. With the various limitations in mind, the state was chosen as the economic entity for consideration.[5]

Methodology.

Several methods of procedure might be employed in studying a specific region. The one most frequently used, and the one which probably offers as few difficulties as any, is that involving comparison of the region of particular interest with other regions having similar characteristics. The extent to which this line of approach, unsupplemented by additional investigation, can offer an understanding of functional relationships between regions, appears to be sharply limited. However, as a point of departure for further examination, it would seem to have its place.[6]

For the purpose of establishing functional interrelations of regions, something in addition to a comparison of their compositions, as they exist at one or at various times, is required. Since forces operating between regions affect the internal economic structure of these regions, determination of the nature and magnitude of such forces is required to identify the causative factors operating within a given area. A direct attempt to identify and establish the mag-

[5]For a discussion of the economic diversity contained within political units, see Lösch, August, "The Nature of Economic Regions", *Southern Economic Journal*, Vol. 5, July 1938, p. 71; also, Vining, D. R., "Regional Patterns of Business Cycle Behavior", *Econometrica*, Vol. 14, Jan. 1946, p. 38; on the rationale of the choice of a state as an intranational economic unit, see Nathan, R. R., "Some Problems Involved in Allocating Income by States", *Studies in Income and Wealth*, Vol. III, National Bureau of Economic Research, New York, 1939, pp. 412-13.

[6]Harris, Seymour E., "New England's Decline in the American Economy", *Harvard Business Review*, Vol. XXV, No. 3, Spring, 1947, pp. 348-371; Hyson, Charles D., and Neal, Alfred C., "New England's Economic Prospects", *Harvard Business Review*, Vol. XXVI, No. 2, March, 1948, pp. 156-180; Hulse, Anne E., and DeTuro, Patrick J., "Economic Problem of the Southeast," *Harvard Business Review*, Vol. XXVII, No. 1, Jan. 1949, pp. 34-52.

nitude of these elements, within the limits imposed by existing data, seems to offer hope of some concrete results. An evaluation of interregional forces requires an examination of the entire pattern of flow of money claims into and from the region, and the goods and service transactions which give rise to the transfers of claims. One method of attacking the problem is to draw up a balance of payments for the small area comparable to an international balance of payments for a nation. Another would be to study the adjustment of the local economy to changing conditions, as evidenced by changes within the banking system.[7] The ultimate goal of this type of study is to construct a regional balance of payments which contains no unfilled gaps so that all money claims moving across the region's boundaries can be accounted for and explained. The movement of balances through the banking system would result as a consequence of the magnitudes of the various items in the balance of payments.

Attainment of this ultimate goal for any state within the United States is a long range project. The lack of pertinent data at the present time limits sharply the extent to which a complete account of the exchange of money claims is possible. Although a certain quantity of statistical data germane to the immediate purpose is available, there are many serious deficiencies which can be remedied only by means of extensive and costly collection of primary data. The immediate results, however, must be considered in light of the anticipated realization of this ultimate goal of completeness.

Components of a Balance of Payments

Commodities move into and from the state by means of railways, roads, waterways, pipe lines, electric transmission lines, and airlines. To assess the magnitude of the effect of these commodity movements upon money flows, it is necessary first of all to determine the physical volume of the goods involved during a given interval of time. Once the physical volume is fixed, prices per unit must be applied to each commodity individually. Since we are concerned with the flow of money claims into and from a state as a consequence of the commodity movements, it is necessary to value outgoing goods at the price received by state residents, and to value incoming goods at prices paid by state residents. The former prices frequently exclude much of the transportation cost of the commodities while the latter prices include most of the transportation costs. This distinction arises from the fact that Arkansas sellers of goods are paid only the price as of their places of business, while buyers in Arkansas must usually pay the factory or primary market price plus costs of transportation to their places of business. In order to determine accurately the inflow and outflow of funds on commodity account, it is necessary to use two sets of prices, one applying to commodities bought outside the state by local residents and the other applying to commodities sold outside the state by local residents.

Besides the commodity trade account, funds are transferred as a consequence of purchases and sales of services across state boundaries. For example, the region's residents pay premiums to insurance companies located outside the state, and the companies make claims payments to beneficiaries who are residents of the state. Also, to a much less extent, non-residents make premium payments to local insurance companies and these companies pay claims to non-residents. Such payments involve money flows of considerable magnitude. Other services, the buying and selling of which lead to interstate money movements, arise in connection with transportation and tourists. It was stated in discussing the nature of the commodity trade account that to be strictly accurate, it would be necessary to use different prices for exported and imported goods, partly because of the element of transportation charges.

The problem of price difference for commodities, depending upon whether they are in or out-moving, could be most clearly handled perhaps by using primary market prices in both instances and drawing up separate freight charge ac-

[7]The first of these two methods is that used by Jacob Viner in *Canada's Balance of Interregional Indebtedness, 1900-1913*, Harvard University Press, Cambridge, 1924; by Penelope Hartland in her study *The Interregional Balance of Payments of New England*; and by R. Dewey Daane in *The Fifth Federal Reserve District - A Study in Regional Economics*. The second method has been used by J. W. Angell in *The Behavior of Money*; B. H. Beckhart and J. G. Smith in *The New York Money Market*; and by Terrill in *The Interregional Balance of Payments of Southern California, 1920-1934*.

counts. This procedure involves a separation of freight charges paid by residents to out-of-state carriers, and freight charges paid by non-residents to "domestic" carriers, since each of these transactions requires payments across state lines. In addition, the quantity of funds flowing out of the state to settle the claims of "foreign" carriers will be reduced by the amount of the expenses incurred by these carriers within the state. Of course, the converse of this holds with respect to commodities carried outside the region for non-residents by local carriers. The net flow on transportation service account would be the difference between the two accounts after correction for expenses incurred by carriers inside and outside the state.

Another important interstate transfer of funds because of service transactions arises from tourist expenditures. Sums spent by out-of-state tourists within the state constitute a transfer of funds into the state, and expenditures by residents traveling outside the state are a reverse flow. The difference between these, if it is other than zero, represents a net flow of claims across the state's boundaries. For certain areas in recent years, the tourist trade has grown to considerable proportions.

Payments are made across state boundaries because of the exchange of corporate securities and interest and dividend settlements. State residents buy securities issued by out-of-state or "foreign" corporations and these transactions necessitate interstate transfers of funds.[8] When these companies make interest and dividend payments to their security holders within the region, a stream of funds flows in the opposite direction. Besides this pair of counter-flowing streams of funds, there are two others arising from the action of local firms in selling securities outside the state and making interest and dividend payments to non-residents. The balance of these four streams for any period determines the net transfer of claims during the interval on private capital account.

Still another occasion for the transfer of funds into and from the state is in conjunction with the receipts and expenditures of the local, state, and national governments. The first two of these are of relatively small importance, as the principal activity of state and local governments which causes interstate movements of funds arises from their deficit financing operations. Bonds issued by state and local governments are sold outside the state of issue. These sales themselves, as well as the oppositely directed interest payments on the securities, when taken in conjunction with the volume of the bonds of other state and local governments sold in the state, together with the interest payments on the foreign securities, result on balance in a net inflow or outflow of money claims. But this constitutes a small part of the total volume of interstate payments stemming from governmental activities. Revenue collections, bond sales, interest payments, grants-in-aid, construction expenditures, pension payments, payments to military personnel, etc., by the National Government are the source of the largest part of inter-state transfers of funds by the government sector of the economic system. Since the size of the sums involved in this major portion of the government account has become so great, it is vitally significant in interregional relationships. In any particular instance it could easily outweigh in importance a number of the other individual factors simultaneously exerting some influence in interregional economic affairs. A net inflow or outflow of funds on the commodity or private capital accounts of a state could be offset or overbalanced by transfers through operations of the federal government.

A more complete treatment of this topic would require a description of the specific procedures and sources employed in compiling the requisite data.

[8]It is assumed here that the buying of such securities represents a net increase in the quantity of claims held against non-residents by local residents.

FINANCING THE DEVELOPMENT OF INDUSTRY IN ARKANSAS*

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One of the traditional deterrents to industrial development is a shortage of local money capital for the purpose. Arkansas is by no means unique in this respect. Preliminary study indicates that the shortage here is more acute than in the more highly developed industrial states.

In the case of industry native to Arkansas, the problem is primarily one of financing new and expanding small firms. Small firms everywhere have more difficulty in securing funds than do their larger competitors.[1] The larger firms, of course, have access to the capital markets of Wall Street and elsewhere. Small firms traditionally depend on local sources for the bulk of their funds since outsiders are seldom in a position to know or care about the prospects of success of the small venture.

Small firms experience special difficulty in obtaining equity capital. Their sources for this risk capital are usually confined to the savings of the proprietors, their friends, relatives, and business associates, and to retained earnings. Such firms are not in a position to issue securities on a large scale. They are often reluctant to tap even all of those sources of equity capital which are available lest control of the firm should become divided.

Even aside from the issue of control, it must be remembered that the principal source of funds for small firms, the commercial bank, is not in a position to advance equity capital. Most small firms, keeping in mind their desire to retain control of the firm in the hands of the original proprietors, would be quite willing to settle for long-term loans. Here again, however, the activity of the commercial banks is limited. There has been a tendency in recent years for banks to look with increased favor on longer-term loans. It is unlikely, however, that the desires of small business for loans of duration comparable to that of the bonds issued by larger firms will be met by commercial banks. This emphasis by commercial banks on short-term loans is apparently unavoidable. Banks must maintain liquidity for the protection of their depositors, most of whose funds are placed in the banks on a demand basis.

Although difficulties are encountered by small firms everywhere, they are particularly acute for small manufacturing firms in a region, such as the South, whose economic background is predominantly agricultural and commercial. In such regions the average person with savings to invest is less likely to think of putting those savings into a manufacturing enterprise. Such savings usually go into real estate, banks or other financial institutions, or securities issued by governments or large national corporations.

Commercial bank loan policy is also influenced by the economic background of a region or community. Bankers who deal primarily with agricultural and commercial loans become expert at evaluating and servicing such loans, and are more reluctant to handle the comparatively unfamiliar needs of manufacturing.

The problems previously discussed apply especially, although not exclusively, to small manufacturing firms native to the State. The financial problems involved in inducing large out-of-state firms to establish branch plants in Arkansas are different. These firms usually have less difficulty in obtaining the bulk of their financial needs. With the small native firms the problem is to expand at all. In the case of larger outside firms the question is more likely to be where to expand.

As part of a general program designed to promote industrial development, many communities have established some kind of organization to render financial

[1]For discussion of the special financial problems of small business firms see: Dauten, C. A., *Business Finance*, New York, Prentice-Hall, 1948. Kaplan, A. D. H., *Small Business: Its Place and Problems*, New York, McGraw-Hill, 1948.

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assistance to industrial firms.[2] These organizations ordinarily raise money from local businessmen, who expect to profit only indirectly, through increased sales resulting from prosperity generated in the community by increased employment. Financial assistance rendered to industrial firms by these foundations typically consists of the provision of a plant at reduced or nominal cost. Firms utilizing the assistance of such foundations are usually larger out-of-state concerns which have already decided to expand. The help rendered in providing plant space is designed, along with other promotional activities, to make the community involved the most attractive site for such contemplated expansion. Aside from the financial assistance thus rendered (which, nationally speaking, has not been large), these community industrial development foundations are useful as an indication of community support for industrialization.

Presumably these large outside firms locating branch plants in Arkansas will continue to obtain the bulk of their required funds from the national capital markets. Small firms native to Arkansas, on the other hand, must rely largely upon investment by Arkansans. This investment, in turn, is dependent upon savings, income, and the general prosperity of the State. Two indices of such conditions may be useful in appraising the State's economic progress.

Per capita income[3] in Arkansas increased from $305 in 1929 to $778 in 1949. This represented an increase of 155%, compared with the national average increase of 96%. The dollar figure for Arkansas is still well below the national average of $1,330, indicating that there remains much room for improvement.

Deposits[4] by individuals, partnerships, and corporations with Arkansas banks amounted to $608,265,000 in 1950, compared with a total of $130,041,000 in 1939. This represented an increase of 368%, as compared with a national average increase during the same period of 196%. The approximate 1950 per capita[5] figures were $320 for Arkansas and $768 for the nation as a whole.

The few statistics above are in substantial agreement with most indices of the prosperity of Arkansas as compared with the nation as a whole. Such indices generally indicate that Arkansas compares unfavorably as to present conditions, and favorably as to rate of improvement.

It is not possible to determine from the above statistics the exact amount of savings which might be made available for investment in industrial expansion within the State. It is apparent, however, that a substantial portion of the desired expansion of native Arkansas industry could be financed from the savings of Arkansans. These savings are at present not being fully utilized for this purpose.

In 1947, the latest year for which figures are available, expenditures for new plant and equipment[6] in Arkansas amounted to approximately $30.3 million. This compared with a figure of $4.4 million for the year 1939. This seven-fold increase compared with a five-fold increase for the nation as a whole. Value added by manufactures[7] in Arkansas increased from $66,444,000 in 1939 to $265,144,000 in 1947. This increase of approximately 299 per cent compares with a national average increase of 204 per cent.

Such expenditures in Arkansas in 1939 represented approximately 0.9 per

[2]For a brief analytical survey of such organizations see: Thompson, Arthur P., "Plans For Financing Local and Regional Industrial Development", *Arkansas Business Bulletin*, April 1951, pp. 1-6. (Published by University of Arkansas, Bureau of Business and Economic Research)

[3]Source of Arkansas and U. S. *per capita* income figures: *Survey of Current Business*, August 1950, p. 20. (U. S. Department of Commerce, Office of Business Economics)

[4]Federal Deposit Insurance Corporation, Reports of assets and liabilities of insured banks, as of June 30 of each year.

[5]Computed from total figures in F.D.I.C. reports, and *U. S. Census of Population*, 1950, Preliminary Counts.

[6]Source: *U. S. Census of Manufactures.*

[7]*Ibid.*

cent of the State's income[8] as compared with a national average of 1.8 per cent. In 1947, the figure for Arkansas was 2.2 per cent, and that of the nation 3.2 per cent.[9]

These statistics furnish some indication of past progress. Prospects of future progress may be judged by the attitudes and activities of persons in the State. Activities of numerous organizations in the state reflect a desire to encourage industrial development. These organizations include the Arkansas Resources and Development Commission, State Chamber of Commerce, Associated Industries of Arkansas, utilities and other business firms, and various local groups. Several Arkansas communities have organized industrial development foundations to provide plant space for industry.

No current discussion of industrial development would be complete without reference to the war production program. The scale and duration of this program are, of course, not yet known. It is clear, however, that the scope of war production is such as to exert an overwhelming influence on the types and amounts of industrial development which may be expected to take place in the next few years. The nature of the program leaves considerable room for promotional activities by Arkansans. Although Federal government policy exerts some influence on plant location, the decisions generally are made by individual firms, before government contracts are secured.[10]

The position of the Federal government in regard to financing of war plants today differs substantially from that in the early days of World War II.[11] This may be due largely to the fact that the prevailing view of the capability of American industry to meet war production needs is much more optimistic today than a decade ago.

During the last war, the government felt it necessary to finance much of the expansion from federal funds, rather than to ask private enterprise to take excessive risk of possible future losses due to war-induced expansion of productive facilities in excess of normal needs. Most of the financial encouragement along this line today consists of more liberal federal corporate income tax treatment. Specifically, the cost of certain production facilities may, for corporate income tax purposes, be charged entirely to depreciation over a five-year period. The amount of expansion costs which may thus be "depreciated" is contingent upon obtaining from the Defense Production Administration a "certificate of necessity", certifying that the facilities involved are vital to the defense effort. The President has directed that the DPA be lenient in granting such certificates.

Some provision has been made for Federal loans, through the Reconstruction Finance Corporation, to enable firms to expand to meet war contract commitments. The number of such loans, however, has been, and is expected to continue to be, much smaller than in World War II. Under present policies, in other words, the overwhelming majority of war production facilities must be financed without benefit of loans or advances from the Federal Government.

CONCLUSIONS

1. In attracting branch plants of outside industrial firms, financial problems are not of prime importance. Community industrial foundations, can, however, be useful in attracting such industry.

[8]Income figures: Total income payments to individuals; compiled by U. S. Department of Commerce, Office of Business Economics; *Survey of Current Business*, August, 1950, p. 19. Figures for expenditures for new plant and equipment obtained from *U. S. Census of Manufactures*. It should be cautioned that such figures represent expenditures in Arkansas, rather than by Arkansans. It is impossible to determine from existing information what percentage of Arkansas income is actually invested in Arkansas industry.

[9]The percentages for the neighboring state of Louisiana in both years were approximately double those for Arkansas.

[10]Address by Victor Roterus, (Acting Chief, Area Development Division, Office of Industry and Commerce, U. S. Department of Commerce) before the Northeastern Conference of State Development Agencies, Albany, New York, January 26, 1951.

[11]*Ibid.*

2. In the case of industry native to Arkansas, financial problems are of greater importance. The crucial problem here appears to be provision of equity and long-term loan capital for new and expanding small firms.

3. The problem of channeling local funds into industrial development in Arkansas appears to be aggravated by the economic background of the state. A sharp increase in investment by Arkansans in the development of native industry may probably be expected only with a change in the economic climate and financial attitudes.

4. It might be desirable to finance all of the projected industrial development without "importing" capital into Arkansas and "exporting" profits. The desired rate of industrial expansion, however, will almost certainly require considerable outside financial assistance.

5. Such indices of prosperity as income and savings data generally indicate that Arkansas compares unfavorably with the nation as a whole as to present conditions, but favorably as to rate of improvement.

6. The activities of numerous organizations and agencies within the State indicate considerable interest in industrial development. Actual expenditures for new plant and equipment are less encouraging.

7. The present war production program presents an opportunity for acceleration of the State's industrial development. Most of the actual financing of this development, however, must be done without direct federal assistance.

THE CONTRIBUTION OF AUTOMOBILE TRAVELERS TO THE ARKANSAS TOURIST INDUSTRY*

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A nationwide study of the vacation travel market, undertaken by the Curtis Publishing Company,[1] indicated that vacation travel in the United States is a seven billion dollar business. This figure is an underestimate of the importance of the tourist industry because vacation trips were defined as three days or longer and estimates were made only of tourist expenditures. Few other statistics evaluating the tourist industry have been prepared on a national basis but many states, realizing its importance to their economy, have attempted to study tourist habits and expenditures. These studies have revealed that the tourist industry, both in dollar value and in total payroll, is one of the most important industries in many states. In California, for example, this industry is ranked higher than the movie industry.

In order to expand and develop the tourist trade many states have engaged in extensive promotion and have set up agencies whose sole function is the stimulation of the tourist business. Florida and California both spend in excess of $1,000,000 a year to advertise their recreational attractions. Arkansas' neighboring states of Missouri, Oklahoma, Tennessee, and Texas, each spend more than $150,000 a year for the same purpose.

In view of the importance of the tourist industry and the fact that Arkansas is competing for tourist dollars in a national market, it is essential to study the characteristics of this Arkansas industry, the facilities and attractions the state has to offer, and the factors restricting or stimulating further development. Several steps have been taken in this direction. The Tourist Industry Committee of the Arkansas Economic Council, functioning as a part of the CED program in Arkansas, has carried on research in several directions: a study of tourist habits and expenditures in Arkansas; an analysis of Chamber of Commerce programs, local problems, and suggestions for increasing the attractiveness of the state; a study of programs and plans of Arkansas private and public agencies which are concerned with the tourist business; an analysis of budgets, organization, programs, and plans of tourist promotion agencies in other states; a compilation of an inventory of existing recreational attractions and facilities in Arkansas.

In this paper, discussion will be restricted to studies which have been made of expenditures and habits of out-of-state tourists. The several methods which have been used to obtain this information will be described and the results of a study covering the period September, 1949--August, 1950, will be summarized.

The University of Arkansas Institute of Science and Technology and the Arkansas State Highway Department, in cooperation with the U. S. Bureau of Public Roads, have conducted experiments with methods for studying tourist habits and expenditures in Arkansas. Two distinct approaches were tested. The first approach, employed during the period July--September, 1949, involved distribution of questionnaires to tourists through Chambers of Commerce, service stations, state police, national forests, national and state parks, Corps of Engineers lakes, hotels, restaurants, and tourist courts. This method attempted to obtain a random sample of tourists visiting Arkansas by distributing questionnaires widely throughout the state. However, two sources of bias existed: the primary distributor and the tourist. Differences in effort put forth by various distribution channels could easily have caused over or under representation of certain

[1] *The Vacation Travel Market of the United States*, The Curtis Publishing Company, Philadelphia 5, Pennsylvania (1950).

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groups.[2] There was the added difficulty that tourists contacted within the state tended to lose the questionnaire or mail it in Arkansas before they could give complete answers to all the questions. Because of these difficulties less than a 1 per cent return was obtained and a very small sample resulted. In addition, there was no way in which total figures could be estimated since information was not available concerning the total number of tourists visiting Arkansas.

The second approach, employed during the period September, 1949--August, 1950, involved distribution of a similar questionnaire by Arkansas State Highway Department personnel stationed on highways leading into the state. The number of survey stations manned varied during the year in roughly the same proportion as the flow of tourist traffic. For one day each month Highway Department interviewers stopped all out-of-state passenger cars which passed the station during daylight hours. Stations were manned on different days of the week in order to avoid the bias resulting from concentration of personnel at any one station on heavy-traffic days. For several months incoming tourists were stopped but because of the low percentage return--about 5.5 per cent--it was decided to contact outgoing tourists. This proved to be a superior method and resulted in a 12 per cent mail return during the first month it was in operation and a 20 per cent mail return thereafter. In November, survey crews began testing the practicability of interviewing tourists rather than giving out questionnaires. The method finally adopted involved interviewing as many outgoing tourist parties as traffic volume would allow and passing out questionnaires to the rest. This method resulted in high percentage returns which ranged from 20 per cent in December, 1949, to 87 per cent in May, 1950.

During the year September, 1949--August, 1950, 1,735,911 out-of-state tourist parties visited Arkansas of which a sample of 15,014, or 1 per cent, was obtained.[3] Although sample size varied from month to month, both in absolute terms and as a per cent of total tourist traffic, coverage was broad enough to justify analysis by months. The questionnaires employed during the year covered by the study permitted analysis of the following points: home state or region of tourists, occupation, size of party, accommodations used, length of stay, expenditures in Arkansas by type, reasons for visiting Arkansas, attractions visited, suggestions for improvement, and favorable impressions.

Out-of-state visitors to Arkansas came from 46 states, the District of Columbia, three territories, and seven foreign countries. More than 52 per cent of the total, however, came from the neighboring states of Texas, Missouri, Oklahoma, Louisiana, and Tennessee. The neighboring regions--South Central and North Central--were the most highly represented, accounting for 47 and 38 per cent of the tourist parties respectively.

The most important occupational group was that including proprietors, managers, and officials, followed by the groups including clerical, professional, and skilled workers. The average party size was three persons. However, nearly 39 per cent of the parties covered by the study were made up of two persons, the most common party size. Tourist courts and homes of friends and relatives were the most popular types of accommodation, resort and commercial hotels together being patronized by only 16 per cent of the tourists. The average length of stay was 3.8 days but nearly 70 per cent of the tourists stayed less than four days, resulting in a modal or most common stay of 1.5 days. Large parties generally did not remain long in Arkansas but as length of stay or party size increased, homes of friends or relatives increased in popularity.

Tourist expenditures in Arkansas were small; more than 40 per cent of the tourist parties spent less than $20 and about 85 per cent spent less than $100 during their stay in Arkansas. During the year average per party expenditure in Arkansas ranged from $45 in May, 1950, to $84 in October, 1949. The weighted

[2]It has since been determined that the excellent cooperation received from hotels in the state caused over representation of tourists who used these facilities. Since these tourists typically spend more than those using other facilities an overestimate of total expenditures resulted.

[3]It must be noted that only automobile tourists are covered by this method. An accurate procedure for evaluating the contribution to the tourist industry of visitors using other means of transportation has yet to be devised.

average for the 12-month period was approximately $60. The application of this average to the Arkansas State Highway Department estimate of the number of tourist vehicles entering the state during the 12-month period indicated that total expenditures in Arkansas of out-of-state automobile tourists were approximately $100 million.[4]

Average expenditure increased as length of stay increased but, contrary to expectations, did not show a tendency to increase as party size increased. Visitors from neighboring states tended to spend less than visitors from more distant states. The three occupational groups, proprietor, manager, and official, clerical, and professional, made higher average expenditures than other groups. Average expenditures varied substantially according to accommodations used, the highest being made by those staying in resort hotels and the lowest by those staying with friends and relatives.

A breakdown of total expenditure revealed that food and meals, the most important category, was responsible for 34 per cent of total expenditure. Other types of expenditure accounted for the following proportions of total spending: automobile expense, 23 per cent; lodging, 19 per cent; miscellaneous, 13 per cent; entertainment, 11 per cent. Tourists visiting friends and relatives spent proportionately less for lodging and more for automobile and miscellaneous expenditures than did those using other types of accommodation. As length of stay increased tourists tended to spend proportionately less for food and more for entertainment, the other percentages remaining fairly constant. As party size increased expenditures for food rose proportionately while those for lodging and entertainment fell. The professional, proprietor, and clerical groups tended to spend proportionately more for lodging and less for automobile expense than did the other groups listed in the study.

The most important reasons listed by tourists for visiting Arkansas were to visit friends and relatives, to reach other states, and to sightsee. The most popular attractions were Hot Springs, the Little Rock area, the Ozark National Forest, Norfork Lake, Eureka Springs, Bull Shoals Dam and the Boston Mountain area. Arkansas highways were the most frequently criticized--more than 74 per cent of those making suggestions for improvement indicated the need for better roads. The scenery and the hospitality and friendliness of the Arkansas people created the most lasting impressions; they were listed by 56 and 36 per cent of the tourists respectively.

This study emphasizes the importance of the tourist industry to Arkansas. An expenditure of $100 million by out-of-state automobile tourists was reached in spite of the short length of stay and small expenditure of the typical visitor. Average expenditure was small because of the large number of tourists who were en route to another state or who came to Arkansas for the primary purpose of visiting friends or relatives. A program to develop the tourist industry should attempt not only to increase the number of tourists visiting the state but also to increase the average length of stay and average expenditure of these tourists. Such objectives could be accomplished by exploiting the recreational assets of the state, by improving the highway system; by increasing knowledge of the state's attractions on the part of the people of Arkansas, and by making additional publicity efforts both within and outside the state.

[4]This estimate excludes expenditures of tourist parties who did not stay overnight in Arkansas. Although individually these expenditures would be small, the large number of parties involved--934,778 from neighboring states--would add a considerable amount to the total.

THE PLANNING AGENCY IN STATE GOVERNMENT*

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Development of State Planning

Before 1933, little had been done in the way of state planning. Previous to that date, Wisconsin and New York had made a beginning in the field. With the creation of the National Planning Board in that year came the impetus which resulted in the creation of state planning boards in nearly every state of the nation.

In 1933, the National Planning Board suggested to the governors of the various states that they create state planning boards in order to aid the federal government in public works planning. The response was overwhelming, and within two years 47 states had created such boards.

State planning boards were granted federal aid if they met certain conditions. The major conditions imposed on the states involved: the appointment of an unpaid planning board by the governor consisting of at least four state department heads as well as citizens, assurance by the governor that he would sponsor legislation to put the planning board on a continuing basis, securing by the governor of necessary personnel to staff the board, development of a planning program, selection of a qualified planner to direct the work, and willingness to cooperate in an interstate agency if one was formed. In return for meeting these conditions, the National Planning Board assigned full-time consultants to the state agencies, assigned relief personnel to help carry out its program, and offered to coordinate their activities.[1]

No two state planning agencies were similar as to programs undertaken. The state agencies cooperated with the National Planning Board especially in making inventories of various resources of the nation. Generally, the work within the state agencies was not too well coordinated.

In the late 30's the number of active planning agencies began to decrease as state legislatures failed to make appropriations. With the abolition of the National Resources Planning Board in 1943, the position of the state agencies was further weakened.

With the entrance of the United States in World War II, many agencies aided governors with war planning and later post-war planning. After the conclusion of the war, a few agencies were abolished, and a number of others had their functions transferred to development agencies.

State planning and state development agencies have dealt with a number of problems. These have included: land use; water and mineral resources; economic surveys and industrial development; industrial promotion; tourist promotion; state public works, highways and airports; social services including health, education, and recreation; the general role of state development; and management planning and research.

Organization of the State Planning Agency

State planning agencies have been headed by an unpaid commission or board. This was the direct result of one of the conditions set forth in 1933 by the National Planning Board if states desired federal aid. It also followed the general policy of making a public agency multiheaded in order to protect it from politics and outside influence. When a permanent staff is maintained for the planning agency, the director of the staff is in theory responsible to the commission, and in theory the commission determines the planning policy.

In practice, the organization functions differently. Planning is a comprehensive matter and it is difficult to find persons who have the background and

[1]National Resources Board, *State Planning* (Washington: United States Government Printing Office, 1935), pp. 8-9.

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the time to serve on an unpaid commission that is to formulate planning policy. A director of one state planning agency made the statement that while his commission was composed of capable men, the commission accepted the policies of the planning director.[2] Perhaps it is too much to expect persons engaged in a full-time pursuit of their own to find the time to become acquainted in any detail within the broad field that state planning encompasses.

One of the arguments used to support the commission type agency is that it gives different interests representation on the planning agency. But can such representation be broad enough at the state level even on large commissions? One representative, of say business, is not representative of all types and kinds of business.

The commission form does relieve the planning staff of political pressure and interference. A change of administration does not generally effect the planning staff. This is vital if long-range unbiased planning is to be accomplished.

There may at times be a need in the planning agency of utilizing an advisory committee to work on a specific problem. When such a committee is deemed advisable, broad representation can be secured. This would provide the planning agency with the opportunity of conferring with and seeking the advice of the committee on the particular problem. The North Carolina State Planning Board used such a committee successfully in studying children and youth in 1946.

A properly organized and staffed planning agency can relieve the governor of much pressure brought against him by varying interests. The agency can provide the governor with an almost unlimited source of nonpartisan information produced by the best brain power and experience the state has to offer. When the agency has the confidence of the governor and is respected by those who work with it, it can save the state many times the cost of its operation and contribute to improved state government.

The Need for a State Planning Agency

In a departmental system of state administration, there is a number of weaknesses that can be strengthened through proper use of a state planning agency.

One of these weaknesses is the lack of coordination and combined action among departments. State government has become so complex that the governor cannot personally coordinate its activities.

Another weakness is the lack of technical advice from the best expert opinion. Employees of the state are generally so busy with their day-to-day tasks that they do not have opportunity to give adequate attention to long range problems.

There has generally been a lack of an organized thinking body in state government which can take the initiative in submitting to the governor, and through him to the legislature, the long-range programs which seem of little importance at the moment to the average law-maker and citizen.

Department heads are generally busy satisfying public opinion, not creating it. The need for an agency that can present facts to the public is genuine.

The utilization by local political subdivisions of the powers and responsibilities granted them in the planning field under the state constitution and legislative enactments generally fall far short of expectations. An agency is needed that can provide technical and advisory service to aid those local units in developing their own programs for improvement.

The Functions of a State Planning Agency

If the need for a state planning agency is recognized, the functions of the agency become apparent.

A basic function of the state planning agency is to gather information, through research, on the various problems and resources of the state and to pre-

[2]Hayden Johnson, former director of the Tennessee State Planning Commission, made this statement to a graduate planning seminar at the University of North Carolina in 1947.

pare long-range plans concerning those problems and resources for the governor for his approval and action. In the preparation of these long-range plans, consideration must be given to the programs and activities of the various state departments in order to prevent duplication of effort.

The planning agency can serve a useful function by aiding the governor with the preparation of legislation, especially that of a technical nature.

The state planning agency can serve as a clearing house of information between the various agencies of state government and between local governmental agencies and the state.

A technical and advisory service should be provided by the state agency to aid local governmental units with their planning problems and programs.

The state planning agency should not be assigned administrative functions, that is, made responsible for the execution of any plan or program. When supervisory or administrative functions are assigned a planning agency, the planning function suffers.[3] Planning is a full-time job itself.

The Theories of Functions of a State Planning Agency

Three theories of functions of a state planning agency can be recognized at the present time. These theories are:

(1) The reorientation theory
(2) The development-planning theory
(3) The planning-development theory

The first of the three theories is concerned with coordinating state services and giving these existing services a long-range development plan. The latter two theories are concerned with the physical development of the state, geared to a long-ranged plan, and differing as to emphasis and procedure.

The reorientation theory holds that the function of the planning agency is to prepare long-range plans for the activities of the various departments in cooperation with the staffs of those departments.[4] This theory recognizes that long-range comprehensive planning is desirable for every activity carried on by state government. This theory also recognizes that department heads are often too busy to plan for future needs and changes, and that the department head is not in position to coordinate his department's program with the programs and plans of other departments. The planning agency thus provides the assistance to get the planning done, and being interested solely in the state's betterment rather than individual service, can coordinate the various plans into a comprehensive state plan.

The reorientation theory holds that state agencies charged with the administration of various programs must themselves become a part of the planning process that develops the programs. If the administrative agencies are to take part in the planning process, department heads would have to be made free from day-to-day tasks in order that they may turn their attention to the development of long-range plans and programs.

The planning agency takes on the role of a catalytic agent by getting the various state departments together to work out plans and programs. This of course would be an ideal solution to carrying out the planning function. However, certain practical problems may arise. In a corporate form of organization, the head can direct the subordinate units to present a unified program or plan before any consideration will be given to budgets. There is no escape around the head. In state government, this may not always be true. Many times

[3]John D. Millett, "Planning and Administration," *Elements of Public Administration*, Edited by Fritz Morstein Marx, (New York: Prentice-Hall Inc., 1946), p. 132.

[4]John E. Ivey, Jr. advanced the reorientation theory in his graduate planning seminar on State Planning at the University of North Carolina in 1947.

Ivey held that the broad policies and procedures which had been followed by state planning agencies had not produced, to that date, as effective a working relationship as might be desired either within state government or among the people of the state. These unsuccessful policies and procedures were: "(1) planning and administration should be separate responsibilities; (2) the planning board should make the plans and turn them over to other branches of government; and (3) the planning process should be executed through an advisory relationship between the planning board and other branches of State government."

independent and semi-independent bodies will attempt to by-pass the governor and appeal directly to the legislature if the governor does not agree with the proposed programs. The governor, through proper utilization of his planning agency, could present to the legislature a strong case for his position and keep state agencies in line with his program.

The development-planning theory emphasizes the development of the resources of the state and the promotion of industry within the state.[5] This emphasis is justified on the grounds that it makes possible a higher standard of living and that this automatically results in better health, greater security, and the various other things that government ought to promote. The agency under this theory encourages the location of new industry within the state and expansion of existing industry using the various concessions granted by the state and local areas as major advantages. These concessions take many forms including tax exemption, free buildings, free or less than cost municipal utilities and so forth.

The planning-development theory places its emphasis on adequate governmental services for the state in general and for industrial areas (actual or potential) in particular.[6] The main effort in this theory is to strengthen local communities through encouraging them to have available adequate services and facilities. Attention is given to the adequacy of such items as power, water, fuel, recreation facilities and programs, schools, housing, municipal finance and administration, and similar other items.

The development-planning theory and the planning-development theory each have strong advocates, especially in the southern states.

South Carolina and Mississippi are typical of the states supporting the development-planning theory. The act creating the State Agriculture and Industrial Board in Mississippi includes the following declaration of policy:

"That the present and prospective health, safety, morals and pursuit of happiness, right to gainful employment and the general welfare of the citizens demand as a public purpose, the development within Mississippi of commercial, industrial, agricultural and manufacturing enterprises..... That the accomplishment of the things herein authorized to be done by the several municipalities will give to them local benefits peculiar to each."[7]

The planning development theory receives support from Alabama, Virginia, and especially Tennessee. Tennessee grants that new industries will often make community improvements possible, but the fact remains in their mind that a community must be attractive as a place to live if industry's attention is to be invited. The director of the Tennessee State Planning Commission wrote in *State Government* "We of Tennessee sometimes shudder at the extent to which *development* predominates in some states and planning, particularly at the local level, is made a step-child of the state program."[8]

The planning-development theory has also received support from leaders in industry. Responsible individuals of a number of leading industrial firms have stated that in looking for new locations that community services and facilities receive prime consideration. Good schools, housing, recreational facilities, stores, and local government are important. Concession on taxes and municipal services are not requested or even desired. This attitude was amply expressed by S. B. Williams, Director of Public Relations, Sylvania Electric Products, Inc., in a talk before the annual meeting of the Association of State Planning and Development Agencies in 1950. Williams said: "We feel that taxes are the only way a community has of raising money to pay for necessary municipal expenses. We want to pay our share the same as anybody else, but we want to be sure that the taxes are fair. If we don't pay our share someone else has to pay it. Perhaps at a later date we, too, would be paying a part of someone else's taxes, and that we wouldn't like."

[5]Albert Lepawsky, *State Planning and Economic Development in the South*, (Kingsport: Kingsport Press, 1949), pp. 81-83.

[6]Ibid., pp. 81-83.

[7]Ibid., p. 82.

[8]Harold V. Miller, "State Planning and Development-Tennessee Style," *State Government*, Vol. 23, No. 7, (July, 1950), p. 150.

The future course of the planning agency in state government is not a set one. There is no doubt need for basic reorganization within state government itself if the planning function is to be able to operate most effectively. The actual program that a state agency will undertake and the emphasis placed on the constituent parts of the program will vary from state to state. However, it is important that neither the planning or development function be neglected if the state is to advance not only economically, but socially and politically.

THE ESTABLISHMENT OF A DICTATORSHIP IN FLORENCE IN 1342*

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The Florentine revolution of 1342 offers an excellent illustration of what modern historians, such as Kenneth Setton and Alfred von Marten, call the proto, or first Fascism, of the Renaissance.[1] It was as a result of this insurrection that Walter of Brienne was made Lord of the Republic.[2] The Council of the People bequeathed to him dictatorial perogatives. It was at the new dictator's behest that the Ordinances of Justice were prorogued.[3] The security and liberty of the Republic were no longer to be predicated upon the constitutional tradition of the state, but upon the whim of Lord Walter of Brienne.[4]

Why was the state subverted? Why were the liberties of the Commune surrendered?[5] Why was the authority of the Priors eliminated?[6]

To answer these questions we must go back into the thirteenth century; for it was in that era that Florence began her large-scale commercial relations with England, France, and the Levant.[7] Into these distant lands the enterprizing merchants of the Red Lily exported vast amounts of capital. Great financial risks were taken in the barbarous countries to the north and the luxurious lands to the east. But these great risks were taken at high interest rates. The fate of these ventures was predicated upon political and economic contingencies over which neither the *popolo grasso* (burghers) nor their government had the remotest control. The magnitude of these loans reached such a point that the prosperity of the Republic was tied to the economies of "divergent and distant countries."[8] The safety of these loans was put in jeopardy at the turn of the fourteenth century. With the decline of the closed economic system of feudalism there was a breakdown of the traditional safeguards of internationalistic culture and law.[9] Foreigners were placed outside of the culture and extra-legally outside of the law.[10] Villani was disturbed by the hatred of the Londoners for the Florentine capitalists.[11] This xenophobia was not confined to London, nor to England, but was a frame of mind prevalent throughout all of Europe. Nor was it directed solely against the Florentines, but rather it was a characteristic of the revival of nationalism which Sapori believed transformed Europe into an armed camp in the early fourteenth century.[12] This hatred for the *Auslander* vent itself on different groups in the following centuries: the Italians in the fourteenth, the Papacy in the fifteenth, and the Germans in the sixteenth century.[13] But in each case it was a reaction against exploitation, guised in the monarchical cloak of national indignation.

By the decrees of May 6, 1339, Edward III of England suspended payment on his obligation to the Bardi and Peruzzi, two of the most powerful of the Florentine banking houses.[14] According to Villani, whose experience in Italo-English banking affairs was great, the suspension involved the loss of 1,365,000 golden florins.[15] Estimates vary on the amount of the default. Sapori states that two thirds of this figure is nearer the truth.[16] In either case the loss in monies was at least three times the total annual revenue of the Commune of Florence.[17] Schevill contends that the annual revenue of the Republic was more than the King of Naples could extract from his entire realm in any given year.[18]

The English historians, Russell[19] and Rhodes,[20] concur in the opinion that Edward's treatment of the bankers of the Republic of the Red Lily was shabby. But from the Englishman's point of view it was a rather inexpensive method of keeping a militaristic monarch in gold.

The repudiation of the Italian debt by the English was but one of the several disasters that overtook the Republic on the Arno during this period. The armies and the diplomats of the Commune had been thwarted in their diverse imperialistic schemes, conceived to achieve suzerainty over all of Tuscany. This aspiration was dashed in October of 1341 when the Pisans captured the city of Lucca. The Florentines at this time may well have recalled the invective of Dante, "A curse upon Pisa! May the Arno be dammed at its mouth, and drown all

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Pisa, man and mouse, beneath its raging waters."[21] In pursuit of status in foreign affairs and stability at home, the government had contracted a debt of more than 800,000 golden florins.[22] The *Pistoian Chronicle* relates that "the *popolo minuto* (working class) began to speak harshly of the *popolo grasso*."[23] Machiavelli writes that the people condemned the governing classes even in their conversations in the streets and the market places.[24]

The ruling oligarchy had not only lost a major war, but they had made unwise expenditures, and failing to provide for the immediate needs of the subject population, consequently lost their support. This loss of confidence stemmed from their ineffectual handling of state affairs. Paoli contends that these conditions were a result of inexperience rather than of the malicious intent of the oligarchy.[25] The government was in such dire straits that it had to advise its allies, the Papacy and the Kingdom of Naples, of its inability to advance them certain monies for mutual defense.[26] Nor could it aid the bankers in securing the requisite wool necessary to keep the weavers employed.[27] An increase in the rate of taxation might have salvaged the state, but the English default on its Florentine loans, coupled with the first battles of the Hundred Years war, had curtailed trade with the North. It was on just that trade that the prosperity of the Republic depended.

Florence faced a seemingly hopeless economic situation. There was no solution within the traditional republican nexus. Bankruptcy forced the Commune to suspend payment on the state debt. The business men recognized that their ruin was imminent on two levels. In order to make restitution, their fortunes would have to be placed at the disposal of their hungry creditors. In addition, the halcyon days of their political power would end with their loss of prestige. To prevent this and to preserve the last vestiges of their influence, they had selected a dictator.

To retain control of the financial policies of the Commune, the magnates agreed to sacrifice sovereignty in foreign affairs to Walter of Brienne.[28] To this end, full power was given to the Count of Brienne in September, 1342. The limit of one year that had been placed on his *Signoria* in July was removed; he was proclaimed Lord of the City of the Red Lily for life.[29] He was supported by all of the orders. The *popolo minuto* favored Walter over the oligarchy since the latter had failed to bring the Pisan War to a successful conclusion. The *grandi* (nobles) supported him because they hoped he would recall their exiled relatives from banishment.[30] Machiavelli epitomizes the situation by saying that since the *popolo grasso* could not meet their financial commitments they were willing to free themselves by enslaving their country.[31]

The citizens themselves were responsible for Walter's elevation to power. It had been achieved not through force of arms, but through popular acclimation, midst wild rejoicings. Alarms were sounded; church bells rang out the "Te Deum"; the mob shouted, "Be our Lord," and "Hail the Duke our Lord." Then *il popolo* hoisted *il signore* on their shoulders and carried him through the Piazza. Down from the tower came the flag of the Republic and up went the ensign of Brienne.[32]

Economic conditions were conducive to such demonstrations of enthusiasm. All classes desired a dictator; the *popolo grasso* hoping for a moratorium on debts;[33] the *grandi*, a return to power;[34] and the *popolo minuto*, an end to unemployment.[35] To this end there was a unanimity of opinion unusual in the annals of the history of the city. The classical *tripartizioni* of society ceased to exist for the time being. The nobles, the business men, and the lower orders had acted in harmony and with great dispatch and thus were able to effect a bloodless revolution.[36]

The dominance of one class in the state was, for diverse political, social, and economic reasons, reprehensible to the other orders. Two centuries of Guelph versus Ghibelline, with its honorific blood-letting, had evaporated as a vain myth by the fourteenth century.[37] Two centuries of contention and *vendetta* between the families, revenge and counter-revenge the theme, had brought nothing but suspicion and death in its wake.[38] Two centuries of civil war between the nobles and the *haute bourgeoisie* had brought Florence alternate waves of prosperity and financial crises. Centuries of the hatred of the *malnate* (base born) for those groomed to the purple had disrupted the judicial process.[39] Recent

disillusionment with imperial policy had dashed the high hopes of the Dantes of the age. The grief of Anagni and the shame of Avignon discouraged intellectuals of Petrarch's ilk.[40] It was in the climate of these failures that Florentine public opinion was formed. It was in the atmosphere of these disasters that a decision was reached to establish a *signoria*. Sapori contends that as sanguine expectation for a solution for these problems faded, so in direct proportion did the traditional morality of the classes.[41] He suggests that the destruction of the feudal economy, law, and culture by the artisans, speculators, and workers made the rejection of the old morality inevitable. The priors were expelled from their palace and the Ordinances of Justice were destroyed by a hysterical, emotional *popolo*. The magnates painted Walter's coat-of-arms on the facades of their houses over the traditional emblems of the Republic.[42]

That the officers, laws, and symbols of government should have been sacrificed with such indecent enthusiasm is indicative of a change in political morality; a change which Villani, an eyewitness, ascribed to divine retribution for the sins of his fellow citizens;[43] a change which, even in the time of Dante, was discernible, and in the life of Petrarch was obvious even to the humanist shut off from the world by folios of Cicero.[44] This gradual disenchantment with the existing order was accompanied by a rising sentiment in favor of a political solution to the pressing economic and social problems. It is at best a sentiment. There is little evidence to indicate that any of the orders of citizens contemplated or desired a profound reintegration of the social or economic system. It was a rearrangement at the executive level that was envisioned. This is a characteristic of Italian thought during the Renaissance. Petrarch, Dante, and even Machiavelli posited solutions which were romantic, superficial, and impractical in terms of the complex needs of Italian society.[45] "All can be arighted if we can but find the 'Just Emperor, the 'Good Pope,' or the 'Ideal Prince '" This "Great Man" will in some magic inexplicable way solve the banking problem, the Pisan problem, the employment problem, and the English problem. In the mind of the Italians this was to be secured through the realization of the Ciceronian ideal of establishing concord between the various social orders. This was a great myth in the last days of the Roman Republic and as such was a source of inspiration to Cicero and his friends. It followed that in the fourteenth century this ideal was viewed by the Italian romantics as a solution to their problems. The myth was not discredited until the sack of Rome in 1527.[46]

The establishment of a dictatorship failed to solve the fundamental problems of the Florentine state. Dictators before, and dictators after Walter's brief tenure, were impotent in the face of the complexities of the Italian capitalism. Walter's policy was typical of the Renaissance despot: favor the middle class, kill off any dissenters. Make peace or war in the interests of domestic security, and grant the *popolo minuto* and the *grandi* bread and circuses respectively. An examination of all the documents of the *Archivio di Stato di Firenze* connected with Walter's despotate, from May 14, 1342[47] to August 6, 1343,[48] shows this to be his policy.

The *virtu* of the *nuovi principi* would in some mystical way prove beneficial to all the social classes. Economic and social stability would be obtained, not by changing fundamental relationships, but by establishing that which Alfred von Martin designated as the welfare state of the *haute bourgeoisie*.[49] This solution postulates a return to a static hierarchical society, in which all orders are fixed to that social and economic position at which maximum concord between the classes is achieved. Just where this mythical point was located the despot of the early Renaissance could not say. It remained for the Medici to approximate its location at a later date.

The revolution of 1342 was a rearrangement rather than a reorganization of the state. It substituted the authority of one man for the authority of the *arti maggiori* (greater guilds). Ottokar states that the Priorate was the exclusive property of the *popolani grassi* (wealthy merchants) as early as 1282.[50] The despot was brought in at their behest and he was expected to act in terms of their interests.[51] That Walter failed to do this is indicated by his subsequent overthrow by *la classe plutocratica*. According to Schevill, his ouster resulted from his inability to master the ever deepening financial crisis.[52] It might be well to extend this thesis. It was his attempt to solve this problem that

frightened the middle class. They were desirous of a solution, but not on his terms. Walter's concessions to the *popolo minuto*, (whom he fondly called *le bon popule*), of which there are at least six recorded in the *Archivio di Stato di Firenze*, were attempts to alleviate the situation.[54] Overthrowing the prevailing wage policy, taking the part of the employees against the *arti maggiori*, was more than a just rearrangement of the apex of authority. It was a threat to the security of the church, nobility, and burghers.[55] The dictator was despot within the limits of the security of those orders. Once he violated the limits he was faced with revolution. This was the frame of reference in which the Medici later ruled. This traditional attitude remained constant until the sack of Rome. Guicciardini was the first historian with any real insight into the situation.[56]

Michelet characterizes the spirit of the protoFascism of this age in the words:

> Never was there an age less favorable to...high tendencies...[it was symbolized by] the living materialism of the tyrants and the band of mercenaries, the bourgeois platitude of the man of finance and money. A religion began in the banks of Florence having in gold its real presence and in letters of exchange its eucharist.[57]

[1]Cf. K. M. Setton, "Some Recent Views of the Italian Renaissance," *Report of the Canadian Historical Association* (1947), pp. 10-11; *idem, Catalan Domination of Athens 1311-1388* (Cambridge, Massachusetts, 1948), p. 44; Alfred von Martin, *Sociology of the Renaissance*, trans, by W. L. Luetkens (London, 1944)

[2]C. Paoli, "Della Signoria di Gualtieri VI Duca d'Atene in Firenze," *Giornale Storico degli Archivi Toscani* (1862), VI, doc. 10, 192.

[3]G. Villani, *Istorie Fiorentine* (Milan, 1802), XII, 2.

[4]Marchionne di Cappo Stefani, "Cronaca Fiorentine," *Rerum italicarum scriptores: Recoolta degli storici italiani*...ordinata da L. A. Muratoria (Citta di Castello, 1903), XXXI, 193, R. 552; Machiavelli, Istorie Fiorentine (Florence, 1927), II, 33; Silvano Razzi, *Vite de cinque huomini illustri* (Florence, 1602), p. 40; "Storie Pistoresi," *Rerum italicarum scriptores: Raccolta degli storici italiani*...ordinata da L. A. Muratori (Città di Castello, 1907), p. 175, c. 104; "Cronache Senesi," *Rerum italicarum scriptores*: Raccolta degli storici italiani... ordinata da L. A. Muratori (Bologna, 1939), p. 532, l. 31-40.

[5]This was not the first relinquishment of Florentine freedom. Cf. G. Degli Azzi, "La Dimora Di Carlo Duca Di Calabria A Firenze," *Archivio Storico Italiano*, Series 5, Vol. XLII, 1908, pp. 45-83; 259-304.

[6]F. Sassenay, *Les Brienne de Lece et D'Athènes* (Paris, 1869), p. 206.

[7]O. Metzing, "Das Bankhaus der Medici u. seine Vorlaufer," *Volkswirtschaftliche u. Wirtschaftsgeschichtliche Abhandlungen*, neue Folges, 6 Heft, Jena, p. 76.

[8]H. Pirenne, *A History of Europe* (New York, 1939), p. 386.

[9]*Ibid.*, p. 99.

[10]A. Sapori, *La Crisi Delle Compagnie Mercantile Dei Bardi E. Dei Peruzzi* (Florence, 1926), p. xv.

[11]G. Villani, *op. cit.*, pp. x, 8.

[12]A. Sapori, *op. cit.*, p. 77.

[13]*Ibid.*, p. x.

[14]*Ibid.*, p. 58

[15]G. Villani, *op. cit.*, pp. xi, 88; Ernest Mehl, *Die Weltauschauung des Giovanni Villani* (Leipzig, 1927) p. 2.

[16]A. Sapori, *op. cit.*, p. 77.

[17]G. Villani, *op. cit.*, p. x.

[18]F. Schevill, *History of Florence* (New York, 1936), p. 212; Francesco Balducci Pegolotti, *La Practica della Mercatura*, ed. Allan Evans (Cambridge, Massachusetts, 1936), p. xv. The value of the golden florin, as of 1932, was $2.35.

[19]E. Russel, "The societies of the Bardi and Peruzzi," ed. G. Unwin, *Finance and Trade under Edward III* (Manchester, 1918), p. 227.

[20]W. Rhodes, "The Italian Bankers in England and their Loans to Edward I and Edward II," *Historical Essays by members of the Owens College Manchester* (London, 1902), p. 138.

[21]G. Villani, *op. cit.*, pp. xi, 135; *The Inferno of Dante Alighieri* (Temple Classics), Canto XXXIII, 80-84.

[22]C. Paoli, *op. cit.*, p. 87. He gives the amount as 4000,000 golden florins exclusive of the Pisan war.

[23]"Storie Pistoresi," *Rerum italicarum scriptores: Raccolta degli storici italiani... ordinata da L. A. Muratori* (Citta di Castello, 1907), p. 174, ch. 100.

[24]Machiavelli, *op. cit.*, II, 33.

[25]C. Paoli, *op. cit.*, p. 85.

[26]A. Sapori, *op. cit.*, p. 105.

[27]*Ibid.*, p. 27.

[28]G. Villani, *op. cit.*, pp. xii, 3; Schevill, *op. cit.*, p. 219.

[29]Marchionne di Cappo Stefani, *op. cit.*, pp. 195-6, R. 555.

[30]G. Villani, *op. cit.*, pp. xii, 3.

[31]Machiavelli, *op. cit.*, II, 3.

[32]*Loc. cit.*

[33]C. Paoli, *op. cit.*, doc. 82, pp. 209-10.

[34]*Ibid.*, doc. 57, p. 204.

[35]G. Villani, *op. cit.*, pp. xiii, 8; Marchionne di Cappo Stefani, *op. cit.*, pp. xii, 8.

[36]A. Sapori, *op. cit.*, p. 118.

[37]H. D. Sedgwick, Italy in the Thirteenth Century (Boston, 1933), I, 429.

[38]*The Inferno of Dante Alighieri* (Temple Classics), Canto III, 106-8.

[39]Machiavelli, *op. cit.*, II, 33; Villani, *op. cit.*, pp. xii, 2.

[40]*The Paradise of Dante Alighieri*, Canto XXVII, 55-60; *The Inferno of Dante Alighieri*, Canto III, 58-60; *The Sonnets, Triumphs and other Poems of Petrarch London*: Bohn Library, 1897). p. 136.

[41]A. Sapori, *op. cit.*, p. xiii.

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WHAT IS A RIEMANNIAN MANIFOLD?

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I shall define a Riemannian Manifold by making use of the concepts and notations of Tensor Analysis, but not giving an introduction to them, by first defining an N-Dimensional Manifold; then defining distance between two neighboring points in this space, with the use of the hypothesis of Riemann, in terms of the fundamental tensor (making use of Einstein's summation notation).

Let us consider the idea of a manifold. --- In problems involving two or three variables we can employ a geometrical picture in which two or three variables are coordinates in two and three space respectively. But when the number of variables exceeds three, the corresponding spaces have no physical interpretations, but we can make use of the language of geometry in referring to them.

For a set of coordinates x^i (all latin indices take on all integral values 1-N), we consider the totality of all points, for which all values which these variables may assume, as an N-Dimensional Manifold and denote it by v_n. If we introduce new coordinates x'^i such that they are functions of the x^i, we get the differential of x'^i in terms of the dx^i which suggests the definition of the components of a contravariant vector. --- And hence could define the components of a contravariant tensor of second order.

Now, we consider an invariant function of the coordinates x^i and hence could define the components of a covariant vector and a covariant tensor of second order (subscripts for covariant).

Now consider the positive definite quadratic form $Q = a_{ij}\, x'^i\, x'^j$ then $a_{ij} = a_{ji}$ if a_{ij} is symmetric in all coordinate systems (a_{ij} are used when the tensor character is not known).

Let y^i denote rectangular cartesian coordinates in our v_n. The square of the differential arc is: $(ds)^2 = (dy^1)^2 + (dy^2)^2 \neq \ldots, \neq (dy^n)^2$, which may be regarded as distance between two adjacent points. If x^i are curvilinear coordinates, such that $x^i = x^i(y)$, we can solve for the y^i and get $y^i = y^i(x)$ and hence $(ds)^2 = b_{ij}\, dx^i dx^j$ (a homogeneous quadratic function of arbitrary dx^k, where $b_{ij} = \sum_{k=1}^{n} \frac{\partial y^k}{\partial x^i} \frac{\partial y^k}{\partial x^j}$, are symmetric.

Using the curvilinear coordinate system x'^i, we get $(ds)^2 = b_{ij}\, dx'^i\, dx'^j$ where b_{ij} are functions of x^k and are not necessarily symmetric. But $a_{ij}\, dx^i dx^j$ is an invariant and a_{ij} is a symmetric coordinate system because the dx^k are components of an arbitrary contravariant vector. And hence $a_{ij} = a_{ij}$ hence, $(ds)^2 = a_{ij}\, dx^i\, dx^j$ where a_{ij} is the fundamental tensor. Space in which distance between two neighboring points is so defined, is called a Riemannian Manifold.

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A RANDOM WAVE FORM GENERATOR[1]*

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In physiological research it is sometimes desirable to use electric currents of random wave forms for stimulation. Usually, electric generators used for stimulation produce, besides direct current, sinusoidal, triangular, or square wave electric currents only. Attempts have been made to generate randomized wave forms by electronic means. These circuits, however, are quite complicated and limited in the variety of random waves produced.

It was, therefore, desirable to design a random wave form generator deviating from electronic wave shaping. The generator described in this paper is based upon the following principle: Light emitted from a light source (L) (Figure 1), and passing through discriminating slits (S) and (AS), is reduced in its intensity by a moving paper mask of black paper (M) having the shape of the random wave desired. The paper mask is mounted on a rotating cylindrical drum (RD). The light beam modulated by the paper mask reaches the photocell (P). The photocell produces a photo current of exactly the same wave form as the light beam is modulated by the paper mask.

This random wave form current is a pulsating direct current of recurrent periodicity. The random wave form photo-current can be directly applied to the object to be stimulated. If the output energy is too low, electronic amplification would increase the output.

Description of the Instrument.

The instrument consists of a light source (L) (6 V, 30 cp bulb, supplied by a 6 V transformer) (Figure 1), a drum (RD) of transparent material, such as glass or lucite, driven by a 6 Volt automobile fan motor of variable speed, a ground glass (G) diffusor attached to the slit (S) (2 mm wide), a slit of adjustable width (AS) which acts as a discriminator, a collimating cylindrical lens (CL), and a photocell (P) mounted in a light-tight compartment with its terminals (PT).

The variation of speed of the motor is achieved by a variable resistor (20 ohms, 2A) shunting the rotor of the motor.

The transparent cylindrical drum (Figure 1, RD), mounted on a toothed wheel, is exactly centered. The toothed wheel is geared to the axle of the motor in the ratio 10:1 (10 revolutions of the motor causes 1 revolution of the drum).

The mask (M) of black paper, cut into any desired wave form, is inserted into the drum (RD). A plastic transparent strip, bent into cylindrical shape, should be inserted into the drum (RD) to keep the mask (M) in place and prevent wrinkling and bending of wave form features of the mask.

The discriminator slit (AS) is adjustable from 0.05 mm to 2.0 mm and permits the discrimination of the wave form. The narrower the slit the better the discrimination. However, the output from the photocell decreases with the decrease of the slit width.

To focus the slit (AS) on the photocell, a cylindrical lens (CL) is placed between the slit and the photocell. The lens has a focal length of 12.5 mm.

The photocell (P) is a General Electric barrier-layer cell, Catalog No. 88X565, the current of which is fed into the output terminal. A double-pole-double-throw switch, wired as a commutator, permits the change of polarity of the stimulus (Figure 2).

In case an AC is desired the photocell output (Figure 2) is fed into a transformer. A female four-contact telephone jack permits switching the output of the photocell into the transformer. This transformer has a winding ratio of

[1]This paper was presented at the 33rd Annual Meeting of the Arkansas Academy of Science, May 1949.

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1:1 (200 turns primary and secondary). The core of the transformer is laminated Permalloy. The positioning of the zero axis of the AC is achieved by a potentiometer and commutater in the circuit of the secondary coil of the transformer.

Performance of the Instrument.

Performance tests of the instrument have been made as follows: A representative random wave form has been cut on black paper (Figure 3) and inserted into mask holder (rotating drum). The photo current of random wave form was recorded by a GE recording voltmeter. Output recordings have been made with the same wave form mask for direct current (Figure 4-A), alternating current (Figure 4-B), alternating current output positioned by the positioning circuit (Figure 4-C), and alternating current output, amplified two times of Figure 4-C, positioned by the positioning circuit (Figure 4-D). Figure 4-A shows that the discrimination of the wave form is better than 1% when a slit width of 0.5 mm is used.

Performance tests using a cathode ray oscilloscope as wave form indicator revealed that the lamp used as supply source must have an inert filament in order to prevent a 60-cycle illuminous modulation when connected by a transformer to the power line. However, if a 6 V storage battery is used as power source for the lamp no interfering modulation was observed.

To amplify the random wave form currents (DC or AC) a two-stage amplifier will be satisfactory for most cases.

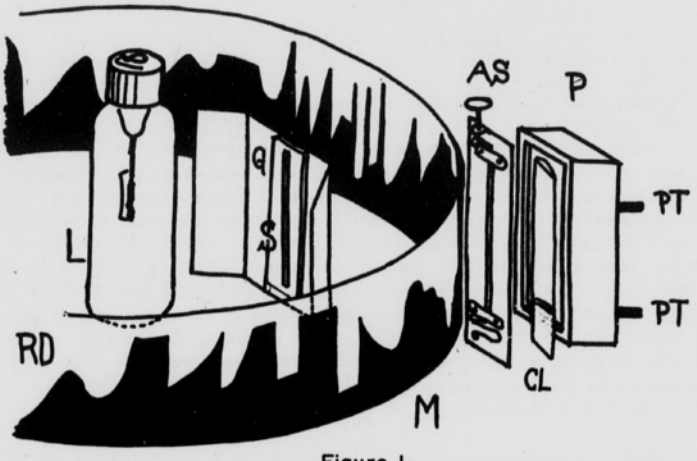

Figure 1

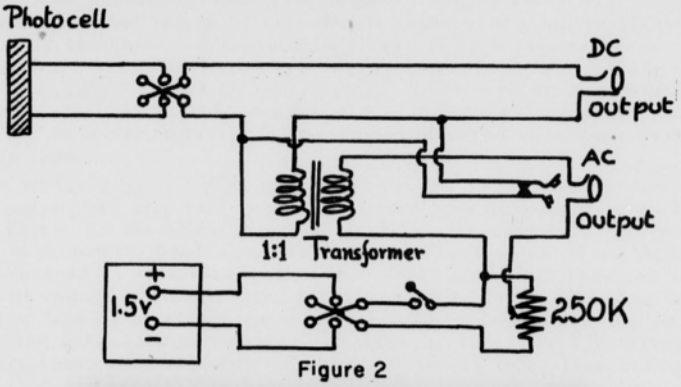

Figure 2

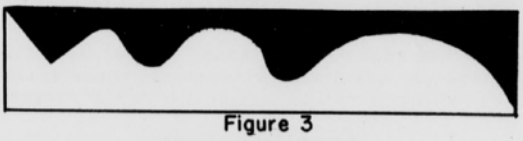

Figure 3

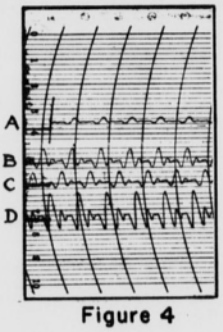

Figure 4

X-RAY INVESTIGATIONS OF ARKANSAS GRAPHITES*

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Two deposits of graphite located in Arkansas have been brought to the attention of the Arkansas Resources and Development Commission. These deposits, located in Garland and Perry Counties, were reported during 1950.

The Garland County deposit was reported by the Hamilton Brothers of Hot Springs. The ore is a black bituminous graphitic shale containing 6.71 per cent fixed carbon as determined by Mr. Troy W. Carney, Chief Chemist, Geology Section, Arkansas Resources and Development Commission. Due to its comparative hardness it was relatively easy to crush the ore to a size of 60 per cent through 48 mesh and 40 per cent through 35 mesh.

John M. Springer of Hot Springs reported the Perry County deposit. This deposit has two distinct forms, clay-ball and shabby-shale. The fixed carbon content of the clay-ball ore was 1.70 per cent, while that of the slabby-shale ore was 1.73 per cent, as determined by Mr. Carney. The softness of the clay-ball ore made it difficult to pulverize to a size of 30 per cent through 48 mesh and 70 per cent through 35 mesh.

The pulverized ore was examined by means of a Phillips Geiger X-ray Spectrometer. The pattern of the Garland County sample revealed a strong association with quartz and traces of Illite. No trace of a graphite pattern indicates an amorphous structure. After simple flotation in a toluene-water mixture, the x-ray analysis revealed Kaolinite ($Al_2O_3 . 2SiO_2 . 2H_2O$) and Illite ($2K_2O . 3MgO . Al_2O_3 . 24SiO_2 . 12H_2O$) in addition to quartz. Beneficiation by a hydrofluoric acid treatment[1] resulted in the removal of the quartz and other impurities. The absence of an x-ray diffraction pattern indicated that this graphite is an amorphous type.

The analysis of the Springer sample proved to be somewhat more difficult. Cuts of pulverized clay-ball and slabby-shale ores were supplied by Mr. Williams and Mr. Carney of the ARDC. X-ray analysis of the clay-ball cut revealed association with quartz, Kaolinite and Illite. The absence of a graphite pattern again indicated an amorphous type. The slabby-shale cut resulted in a similar pattern of quartz and Kaolinite, but with extra lines indicating Sericite, an alteration form of mica that approaches Illite. Flotation by toluene-water did not totally eliminate the quartz, Kaolinite, Illite and Sericite. In both cases, treatment with hydroflouric acid removed all impurities and resulted in a pattern that was essentially background. The graphite, therefore, has an amorphous structure.

The low carbon content of these graphite ores and the necessity of beneficiation by chemical means practically eliminates any possibility of profitable commercial recovery.

[1]Z. V. Harvalik,"Flotation of Graphite from Arkansas Ores", Arkansas Academy of Science, 1951.

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CAN STIMULUS-RESPONSE LEARNING THEORY EXPLAIN ABNORMAL FIXATIONS?*

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Norman R. F. Maier has recently published a challenging book which he calls, *Frustration: The Study of Behavior Without a Goal* (4). In this book Maier brings together the evidence for a type of behavior which he believes falls outside the province of learning principles. The behavior consists of the fixation of a particular mode of response in an insoluble problem situation, a fixation which may persist despite the differential application of reward and punishment when the problem is subsequently made soluble.

Maier advocates a new theory to account for this behavior on the grounds that current learning theories are unable to explain it. This fact makes his work challenging. Do we, in fact, need a new theory to account for Maier's experimental findings? Or, would not a rigorous application of well known stimulus-response principles of learning provide a more adequate account of the behavior in question?

The evidence on which Maier bases his claims comes largely from a series of studies using the Lashley jumping stand. In this situation hungry rats are taught to jump from a small stand to stimulus cards placed side by side in the windows of the apparatus. A rat can be taught to discriminate between two stimulus cards (e.g., a black circle on a white card versus a white circle on a black card) through the simple procedure of locking one of the cards consistently and leaving the other unlocked. The cards are changed from one window to the other in an unpredictable sequence. When the hungry rat jumps against the correct card, the card falls in easily and he obtains food on the landing platform directly behind the window. When he jumps to the incorrect card, he bumps against it and falls into a net three feet below. After a number of such trials most rats learn to jump at the card which is consistently unlocked, choosing it invariably regardless of its position. Position responses also can be taught very easily by having a given side consistently locked and the other consistently unlocked, even though the distinguishable cards are rotated from window to window.

The training condition particularly relevant to Maier's conclusions is the one he has called the "insoluble problem." In this condition the card and position locked is varied in an unpredictable chance order, and the cards are switched from window to window, so that there is no way for the animal to get through to food on every trial. Instead he is forced to bump a locked card and fall into the net about half the time he jumps. As a result, the rat tends to resist jumping and must be forced to respond by punishing him for remaining on the stand. The usual method used to force jumps is to direct an air blast against the hind end of the animal. When forced to jump in such an insoluble problem, the rat nearly always adopts a consistent response, usually choosing a particular window on every trial, but sometimes a particular card.

The basic finding which Maier considers contrary to learning principles and which he believes requires a major revision in current behavior theory, is that the responses which rats adopt in the insoluble problem condition (i.e., where any particular position or card habit is punished as often as rewarded) are much more persistent than responses adopted under continuous reward conditions (i.e., where the correct response is invariably rewarded and the incorrect response is invariably punished).

The persistence of a response, or degree of fixation, is measured by how readily the rat will abandon the response when the problem is changed so as to make some other response invariably lead to reward.

Maier finds that most rats which learn a position habit when a given position has been rewarded on every trial will readily abandon their position re-

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sponse and switch over to a visual discrimination habit if a particular card is always rewarded. On the other hand, rats which have adopted position responses when neither card nor position was consistently rewarded tend to persist in the position response and never acquire the visual discrimination, even though run for hundreds of trials.

Maier maintains that learning principles predict a greater strength in the responses which are rewarded each trial, whereas, the facts prove that responses which are punished as often as rewarded turn out to be stronger as measured by resistance to change. Furthermore, Maier argues, rats fail to abandon a position fixation when the problem is made soluble even though they show in secondary ways that they have "learned which card punishes and which card does not." When the positive, or rewarded, card is in the preferred position, the rat tends to jump straight to it without much hesitation; but when the negative, or punished card appears on the preferred side, the rat hesitates longer and often makes a slanting, "abortive" jump so that he hits the card or an adjoining part of the apparatus with the side of his body. According to Maier, this proves the animal "knows" which is the correct card but cannot control his complusive tendency to continue jumping to the old position. Such behavior is considered by Maier to be qualitatively different from learned behavior, both because of its greater resistance to change despite the persistent use of punishment, and because of its compulsive aspects. These features are said to justify the use of the term "abnormal fixation" in describing the behavior.

The theory of behavior which Maier proposes to account for such findings holds that behavior is governed by two qualitatively different processes: (a) a motivation process, in which learning principles apply and the behavior acquired is governed by the consequences of each response, and (b) a frustration process, in which learning principles do not apply and behavior bears no relation to its consequences. Punishment is seen as having two effects: it can act as a negative incentive and as a frustrating agent. If given in small amounts, punishment acts as a negative incentive, tending to make the subject less prone to repeat responses which lead to punishment. When punishment is severe, however, it serves primarily as a frustrating agent. If, through a combination of punishment and continued failure to adjust, the "saturation point" in frustration is reached, the frustration process takes over and the response in progress at the moment becomes an abnormal fixation no longer subject to modification in line with learning principles.

If Maier's interpretation is valid, some important revisions would be indicated in the roles of punishment and frustration in behavior theory. However, Maier's application of learning principles does not take into account several relevant considerations in modern treatments of learning. So let us make a conscientious effort to apply well recognized stimulus-response principles of learning to Maier's results before we accept his less parsimonious theory.

A major development in stimulus-response learning theory which Maier neglects in the interpretation of his results concerns the role of punishment in learning situations. Maier's position that punishment weakens responses in selective learning situations is no longer held by most stimulus-response learning theorists. Thorndike, whose original law of effect included the principle that punishment weakens responses (6), was later forced to give up this portion of his effect principle. In its place he concluded that the effects of punishment are often unpredicatable and that cessation of punishment can often be treated as a reward, so that both reward and punishment are subsumed under the single principle that reward strengthens the behavior which accompanies it (7, 8).

The latter conception of the role of punishment has been most systematically developed by Hull (2) and others with related theories (5). Whatever responses are occurring at the time punishment ceases tend to be reinforced according to Hull. Often these responses happen to be incompatible with the ones which led to punishment, and, in such cases, the responses which led to punishment tend to be replaced by responses of avoidance. However, such adaptive replacement of responses leading to punishment is obviously not predicted by Hull's theory for all punishment situations.

Guthrie's views are similar in terms of what effects might be expected from the use of punishment. According to Guthrie's theory of learning (1), when

punishment works, it works because the last response to the punished situation (i.e., the response associated with cessation of punishment) is incompatible with the response that brought on punishment. He explicitly predicts that punishment will not be effective in weakening a response if it does not elicit incompatible responses.

Thus if we accept the widely held view that *cessation* of punishment is reinforcing, several aspects of the jumping stand situation assume an importance not discussed by Maier. One such factor is the reinforcement possibilities of escape from the air blast which is blown on the animal when he hesitates on the jumping stand. This would be expected to reinforce jumps to both the negative and the positive cards indiscriminately even in discrimination training and *could* preserve a position habit regardless of differential reward at the cards.

Another consideration dealing with the effects of punishment is that the responses which could be reinforced by the cessation of punishment at the cards (responses made by the rat while falling away from a locked card) are for the most part not incompatible with performing the same jumping response again, although such responses as would be aroused by fear (cringing, etc.) are incompatible to some extent, even though highly generalized to the whole situation. The so-called "abortive jumps," which seem to originate in the animal's twisting away after hitting a locked card, are responses which could be reinforced by cessation of punishment at the cards and are far from incompatible with jumping to the locked card again. Such abortive jumps undoubtedly result in less discomfort to the animal than hard bumps on the nose and might well account for enough of a decrease in resistance to jumping to the negative card to make learning the visual discrimination response highly unlikely.

An additional aspect of Maier's studies which does not enter into his interpretations is that of partial reinforcement. In the insoluble problem the animal practices his consistent response under conditions of partial reward and punishment, getting through to food on half of his trials and hitting a locked card on the other half. Generalizing from the well documented effects of partial reinforcement in conditioning studies, we should expect that responses practiced in the insoluble problem would be more resistant to extinction than responses which had been continuously reinforced. Jenkins and Stanley, in their recent review and critique of the partial reinforcement literature conclude in part:

> The most striking effects of partial reinforcement are apparent in response strength as measured by resistance to extinction. In almost every experiment, large and significant differences in extinction favoring the groups partially reinforced...were found. The practical implication of this principle for maintaining behavior is obvious: Administer the reinforcing stimulus in conditioning according to a partial schedule, and the behavior will be maintained for long periods in the absence of external support from primary reward. (3, p. 231).

Since, on a stimulus-response theory, the response in progress must extinguish to some point below the threshold of alternative responses before an alternative can occur, the partial reinforcement aspect of the insoluble problem assumes considerable importance. The carry-over of effects of partial reinforcement from the insoluble problem, plus the continued partial reinforcement of the response as it persists through discrimination training, might combine to produce "fixation" without its being at all abnormal from the standpoint of learning theory.

But so much for theory. How about some results? I shall now briefly summarize one experiment which I completed last year. Following this, Mr. Crumpler will report an experiment which he has recently completed.

In my experiment, the purpose was to isolate the effects of partial reinforcement and insolubility of problem, two factors which are always combined in the Maier studies. The general method involved training three groups of rats in an initial response under different conditions. This was followed by Maier's usual method of testing in a discrimination problem to determine the extent of fixation. The experimental design was as follows. In two groups the factor of solubility was held constant while partial reinforcement varied, and in two

groups the factor of solubility was varied while partial reinforcement was held constant.

Significantly more fixations were found to result from training in a soluble problem under conditions of partial reinforcement than from training in a soluble problem under conditions of continuous reward, indicating that partial reinforcement alone is enough to produce fixations.

The difference in fixations found between the soluble problem controlled for partial reinforcement effects and the insoluble problem indicated that insolubility works against the development of fixations. A measure of response rigidity in terms of the number of animals which showed variability in the test problem revealed a significant difference indicating that insolubility of initial training conditions makes for less rigid responses than solubility.

Analysis of latency data revealed that the learning of the test discrimination habit is continuous, with differences in latency appearing in the normal course of learning before the animals were making correct choices.

Analysis of abortive jumps revealed that animals which learn abortive jumps during acquisition of the initial response are quite unlikely to learn the subsequent test discrimination.

The conclusions which may be drawn from this experiment are:

1. The factor of partial reinforcement present in Maier's insoluble problem condition is of great importance in producing fixations.
2. The factor of insolubility, when controlled for partial reinforcement effects, works against the development of response rigidity.
3. Differential resistance to the positive and negative cues shown by fixated rats in test training cannot be taken as an indication of abnormality since it is shown to a striking degree in animals which eventually learn the test.
4. Abortive jumps may be interpreted as being learned on the basis of reduction in punishment and, by reducing punishment, interfere with the learning of the correct response.
5. Stimulus-response learning theory easily accounts for the behavior which Maier considers incapable of being explained without a separate set of principles.

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REACTION TIME IN WORD ASSOCIATION

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Within a specifically limited sense, this experiment was a study of the effect of sophistication upon the data obtained from a lie detector. We refer to the reaction time of the subject's response to stimulus words, statements, or questions, which is a part of the polygraph record.

The problem proposed was to observe the reaction time of subjects in a word association exercise when they did not know that reaction time was being measured, and compare their performance with a repetition of the exercise when they knew that the reaction time was the most important part of the word association exercise.

The subjects were 50 college students of various ages and major fields of study. Because of the possibility that students with one or more courses in psychology might be aware of details in the lie detector technique, only five or six of our subjects had taken courses in psychology.

PROCEDURE

In order to control probable effects of other factors, several things were standardized: (1) the same experimenter read the stimulus words throughout the investigation; (2) the same person handled the stop watch and recorded all the data; (3) one list of stimulus words was used in the same order for each subject; (4) the same subjects were used for both the "naive" and the "sophisticated" situations.

The following information was given to the subject by the experimenter:

> I am making a study of students' reactions to certain words. In this study I am using a list of fifty words, which will be read to you one at a time.
>
> Each word will suggest or cause another word to occur to you. I want you to tell me immediately what that word is that comes into your mind. Do not hesitate to say it regardless of what it is, because your name will not appear anywhere in this study, and by tomorrow I myself will not be able to remember who made the responses I have noted.
>
> Now, let us arrange our chairs so that you will have your back to me and will be facing a wall or corner of the room. This will assure that none of my movements will interrupt your thinking, and will reduce the number of objects in your line of vision that might themselves suggest responses.
>
> Before we begin the list we are studying, let us try a couple of practice words. I will say the word and you give me the first word that comes into your mind.
>
> "cat" _____
> "rifle" _____
> "button" _____
>
> I see that you understand what we are doing. Let us now start our list of fifty words.

About a year prior to this study, several hundred words taken from a standard dictionary were submitted to about 300 college students with instructions that they indicate for each word their immediate emotional reaction. They wrote or indicated for each word whether it was pleasant, neutral, or unpleasant in psychological connotation. The words used in this study were those indicated as being neutral by more than 90 per cent of the students, and those indicated as pleasant or unpleasant by more than 90 per cent of the students. The fourteen words italicized were those having favorable or unfavorable emotional loading.

The following fifty words were read to the subject one at a time and the subject's response-word was recorded along with the time required to make the response: light, carpet, high, slow, salt, *sex*, black, lamp, green, *embrace*, scissors, *caress*, blossom, hat, *prostitute*, eagle, cottage, walk, *rape*, ocean, glass, *desire*, bitter, work, *ravish*, tobacco, *kiss*, sour, king, butter, garden, *fondle*, lion, worry, yellow, window, music, *moral*, river, *dream*, tree, *shame*, loud, thirsty, house, *body*, swift, *sin*, window, bread.

Before Trial 2, the following information and instructions were read to the subject:

> Now I want to show you what I have been doing. I have written down your word responses and also the number of seconds you needed to voice the response.
>
> The time element is the important thing, and that is the thing I am watching most carefully. Any delay in response on your part tells me that the stimulus word has embarrassing meanings or associations with *your own past* life. Such a word reminds you of something that is strongly emotional either "good" or "bad," "pleasant" or "unpleasant."
>
> We are going to repeat the experiment just as we did a few minutes ago. This time I want you to be sure that you make the most immediate response possible. I want you to try to conceal the fact that any word has more than average emotional meaning for you by not hesitating to tell me the first word that comes into your mind when I say the words in our list.

The subject and chair were placed in the same position as was used for the first word association test, and the fifty words were repeated.

A change was made in the procedure for the last 22 subjects in that additional data were recorded. A list of indicators other than reaction time was placed before the recorder. Whenever the subject exhibited such an additional indicator in his or her response, the recorder noted it. The extra indicators were as follows:

1. Stuttering in giving the response word
2. Repeating the stimulus word
3. Naming an object within the subject's view
4. Using another stimulus word for response
5. Repeating a response word although not apparently applicable.

ANALYSIS OF RESULTS

The first step in the analysis of the data was to determine the average reaction time in Trial 1 (subject *not* knowing that the reaction time was important) for the non-loaded words. The words given above that are italicized are those that were considered as having emotional loading above the average of the other words for most people. The standard deviation was also determined for each subject.

Each subject's average reaction time (on non-loaded words) plus three of his standard deviations was considered as the delay in response which was large enough to be meaningful statistically. The number of loaded stimulus words with meaningfully delayed reaction time was counted in Trials 1 and 2, and their differences likewise tabulated in Table I. Ths same examination was made for the non-loaded words, as is shown in Table II.

Each of the fifty subjects reduced both the average reaction time and the standard deviation in the second trial, for both the loaded and the non-loaded words.

Symptoms of unusual reaction to stimulus words (other than the reaction time) were exhibited by 17 of the 22 subjects observed, during the first trial. All but three completely eliminated these unusual symptoms during the second trial. Two of the three reduced the symptoms by 50 per cent, the third had the same number of symptoms in both trials.

CONCLUSIONS

The first conclusion was that sophistication (knowledge that reaction time is important in a word association test) may enable a subject to defeat the lie

detection apparatus insofar as reaction time is concerned.

The second conclusion was that the observed symptoms other than reaction time tend to disappear when the subject made an effort to control his reaction time.

It is recommended that further research be made to estimate the learning effect or practice effect -- if any -- that takes place between trial one and two. This might be done by allowing a few minutes rest and then just repeating the list of stimulus words without any additional information or instruction as was given in this investigation.

Another measure of practice might be the use of a control group receiving complete instruction with regard to the importance of the reaction time factor before undergoing Trials 1 and 2 successively. It might be profitable to pursue the question of effect of sophistication upon the subject's response to the lie detector technique in the areas of physiological actions controlled by the autonomic nervous system. It may be that concentration upon control of one factor might seriously influence the normal or expected response if within the functioning of the autonomic nervous system.

TABLE I

NUMBER OF LOADED WORDS WITH
MEANINGFULLY DELAYED RESPONSES

Subject	Trial 1	Trial 2	Difference	Subject	Trial 1	Trial 2	Difference
1	1	0	-1	26	5	0	-5
2	9	1	-8	27	4	0	-4
3	5	2	-3	28	3	0	-3
4	6	0	-6	29	3	0	-3
5	5	3	-2	30	2	0	-2
6	3	1	-2	31	12	2	-10
7	5	2	-3	32	4	0	-4
8	7	2	-5	33	6	2	-4
9	1	0	-1	34	0	0	0
10	2	1	-1	35	5	1	-4
11	7	0	-7	36	6	0	-6
12	3	1	-2	37	2	0	-2
13	4	0	-4	38	3	1	-2
14	2	0	-2	39	4	0	-4
15	4	0	-4	40	4	3	-1
16	3	0	-3	41	3	0	-3
17	5	0	-5	42	3	0	-3
18	7	0	-7	43	7	1	-6
19	4	1	-3	44	6	0	-6
20	5	1	-4	45	3	0	-3
21	5	1	-4	46	0	0	0
22	1	0	-1	47	0	0	0
23	2	0	-2	48	6	0	-6
24	9	1	-8	49	5	1	-4
25	2	2	0	50	6	2	-4

TABLE II

NUMBER OF NON-LOADED WORDS WITH MEANINGFULLY DELAYED RESPONSES

Subject	Trial 1	Trial 2	Difference	Subject	Trial 1	Trial 2	Difference
1	0	0	0	26	1	0	-1
2	0	1	1	27	1	1	0
3	2	1	-1	28	4	0	-4
4	0	1	1	29	4	1	-3
5	1	0	-1	30	0	0	0
6	0	0	0	31	2	1	-1
7	2	0	-2	32	2	1	-1
8	6	1	-5	33	1	0	-1
9	1	0	-1	34	2	0	-2
10	0	1	1	35	2	0	-2
11	3	0	-3	36	1	0	-1
12	1	0	-1	37	2	0	-2
13	1	0	-1	38	1	0	-1
14	5	0	-5	39	1	0	-1
15	3	0	-3	40	1	0	-1
16	0	0	0	41	2	2	0
17	1	0	-1	42	0	0	0
18	2	1	-1	43	1	0	-1
19	2	2	0	44	0	1	1
20	2	0	-2	45	2	0	2
21	7	2	-5	46	3	0	-3
22	0	0	0	47	3	0	-3
23	0	0	0	48	2	0	-2
24	5	0	-5	49	0	1	1
25	2	2	0	50	3	0	-3

LATENT AND MANIFEST FUNCTION IN THE THEORY AND RESEARCH OF BRONISLAW MALINOWSKI

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Bronislaw Malinowski might well be termed the godfather of modern functionalism. He, more than anyone else, articulated theoretically and applied empirically a type of thinking about social organization which had been used by many of his predecessors but without a systematic investigation of its nature and implications. Malinowski's approach, however, is not just functional but, like all functional studies, involves structural elements which exist in functional relationship to one another. Thus, when Malinowski says that his two types of analysis are the institutional and functional, it is equivalent to saying that his approach is structural-functional. Functions are, in fact, an integral part of structural analysis.

Malinowski uses institutions rather loosely as the organized systems of purposeful activities. Their components are: charter, personnel, norms, material apparatus, activities, and function. *(1, p. 52)* Cooperative and organized activities thus grow out of personnel following the norms of their specific positions and using the material apparatus at their disposal. The function of such activities is to be distinguished from the charter in that, while the charter is the explicit traditional or new purpose to be achieved, function is the "integral result of organized activities." *(1, p. 53)*

Summarizing Malinowski's purely theoretical statements of his functional approach, we find the basic structural isolate to be the institution. Function emerges as one aspect of that structure. It is the objective result of the organized purposeful activities of the institution as these results are tied to the needs, that is, to the maintenance conditions or functional prerequisites, of the total social system in general or to parts of the system in particular. Certain basic needs are worked out toward the fulfillment of which men develop direct organized collective responses or institutions. Such direct institutional responses, in turn, require for their very organized existence the fulfillment of certain other emergent derived conditions or needs. These needs emergent at the level of collective organization are called instrumental, symbolic, and integrative. In response to the specific kinds of instrumental, symbolic, and integrative needs, systems of economics, social control, education, religion, magic, knowledge, etc., have developed universally. *(2, p. 942)*

The purpose of this paper is not just to review Malinowski's theory and empirical research, but to see how the related concepts of function and dysfunction, manifest and latent function, fit into Malinowski's theory and can be significantly illustrated by his ethnographic research.

Toward this objective, let us look first at the meaning of function and dysfunction. Function broadly conceived, is the objective consequence of the concrete application of a social process, pattern, status-role, group, or institution. *(5, p. 50)* The first step in isolating function, then, is to isolate the structural parts which are in functional relationship, that is, which have unilateral or interdependent objective consequences. Involved in the ascertainment of the objective consequences of a particular cultural item is the implication that some other cultural item will be affected. That is, the consequences of one cultural item can only be evaluated in terms of its effects upon another. Hence it is logically and conceptually impossible to think of simply "objective consequences" without also limiting the range of effects and asking the question of "consequences for what group, pattern, institution, status-role?"

This involves the further judgement as to the positive or negative, i. e., the functional or dysfunctional, nature of the effects of one cultural item upon another. One can conceivably state the objective consequences without making such a judgment, but most functional studies do involve this type of evaluation. That they do, however, does not imply that there is any acceptance of the ultimate validity of the cultural items and their positive and negative consequences

or that what is functional for one item may not be dysfunctional to another. For instance, it is probable that a system of pre-marital and post-marital marriage counseling clinics would be dysfunctional to the divorce pattern, while equally functional to marital success. Weber's discussion of the immanent functional tendency of the charismatic authority system to become routinized and thus move into the traditional or rational-legal system and the tendency of the rational-legal system to move into the other two types, illustrates the same thing. *(6, p. 363)* Functional and dysfunctional are highly relative terms, the validity of their use depending largely upon one's perspective. That is, just because some particular cultural item is considered dysfunctional to an existing system does not mean that at the same time it cannot be functional to an emerging new system, or that it cannot be at once both functional and dysfunctional to the same system.

In summary of this point, we can say that functional analysis may be the discovery of unilateral causal effects of one part of culture upon another. More frequently, however, functionalism is couched in terms of "interdependent effects." The emphasis here is upon the ways in which the parts of a total system, whether this system be a group, institution or society, inter-influence, mutually affect, and inter-depend among, each other. Consideration of these effects also usually involves a judgment of their positive and negative nature seen in terms of the maintenance conditions of the item affected.

With this as a background, we are in a position to turn to Robert Merton's use of latent and manifest function. *(5, pp. 61ff)* Manifest functions are those objective consequences, both positive and negative, which are intended, purposive. Latent functions, on the other hand, are those objective consequences which are unintended but which are discovered by the observer. Both of these involve objective consequences and are to be distinguished from "avowed purposes." That is, subjective purposes are not function, though the objective consequences of such purposive action, if the consequences are those intended, are manifest functions. It follows that the avowed purpose of a cultural item may not actually result in or may not be subject to evaluation. This is particularly true when the relationship between the pattern and consequence is a non-empirical, imputed, and thus transcendental one. This does not mean, however, that such a cultural pattern cannot have functions of a latent, unintended sort, which explain why it persists in the presence of an irrationally or nonrationally imputed consequence.

Applying these concepts to the theory and research of Malinowski, we note that they fit nicely. For instance, it has been pointed out previously that Malinowski, in his purely theoretical works, distinguishes clearly between "charter," and "function." Charter is the explicitly stated aim of the institution; function is the "integral results of organized activity." By integral results of organized activity, Malinowski means the objective consequences of the institution in the maintenance of the integral or whole society. What difference does the institution make? What prerequisites for a going society does it meet? Malinowski's strictly theoretical formulation of his functional position is limited mostly to stating the functions of universally-found institutional complexes in meeting these basic and derived functional prerequisites.

In his empirical studies, several distinctive things appear. First of all, Malinowski points up the necessity of distinguishing between the negative and positive effects of one item on another, though his major emphasis is upon the latter. In the light of Merton's severe criticism of Malinowski for his exposition of an "ideologically conservative" functionalism which tends to find only positive functions for every cultural item and to regard both the functions and the items indispensable as they exist, *(5, pp. 38ff)* it may seem strange that we would say that Malinowski recognizes the necessity of distinguishing between the positive and negative (functional and dysfunctional) effects of one item on another. We believe, however, that Merton and others who have similarly criticized Malinowski overlook such statements as the following from *Coral Gardens and Their Magic*:

> In my opinion magic has exercised a profound positive function in organising enterprise, in inspiring hope and confidence in the individual. Side by side with this, magical belief has obviously developed an attitude which exerts disturbing and subversive influences,

> especially in witchcraft and black magic. In the history of culture, every phenomenon, I think, has got its constructive and disintegrative sides, its organising functions and its influences which point towards dissolution and decay. Human cultures do not merely grow and develop. They also decompose, die or collapse. Functional anthropology is not magic; it is not a chartered optimism or whitewashing of culture. *(4, p. 240)*

It is true, of course, that most of Malinowski's ethnographic works and theoretical generalizations emphasize positive functional values of the items studied to the exclusion of their negative dysfunctional values and are open to justifiable criticism on that score. The fact remains, however, that Malinowski shows that he is aware of the dysfunctional as well as functional aspects of cultural items.

Secondly, Malinowski's functionalism in his empirical works not only includes analysis of broad institutional complexes but also that of the functional contributions of particular patterns, systems of patterns, and statuses, i. e., *inter*-institutional functions. Thirdly, he implicitly introduces a distinction between the ostensible or manifest function and the un-noticed or latent function. Fourthly, one can find traces of a distinction between the imputed manifest function and genuine manifest functions. Let us proceed to illustrate these concepts in terms of Malinowski's research.

In one place, Malinowski points out that the Trobriand Islanders have a rudimentary matter-of-fact body of knowledge which represents the beginnings of science. They have a body of rules and conceptions

> based on experience and derived from it by logical inference, embodied in material achievements and in a fixed form of tradition and carried on by some sort of social organization ...*(3, p. 17)*

Included in this practical knowledge are the experimentally verified principles of buoyancy, leverage, equilibrium, etc., employed in making a canoe, *(3, p. 17)* the nature of soils and plants, and a fair knowledge of meterological rhythms and sign.*(4, p. 76f)*

In contrast with this type of knowledge and activity, magic is not directed toward influencing nature so as to produce desired empirical ends. Magic is oriented to empirical ends, but not by way of natural forces. It is a pragmatic scheme of definitions developing from the powerful effect of experiences lived through in which man received a revelation of his autonomous power to achieve the desired end apart from or in cooperation with the forces of nature.

Why does magic arise and what is its function? It arises in response to the gaps and impotence of empirical knowledge. It appears "where there is an important human activity which is at the same time dangerous, subject to chance, and not completely mastered by technical means."*(4, p. 217)*

The basic function of magic is to offer man some active attitude toward these unpredictable aspects of his environment in the absence of adequate technological knowledge. It gives him faith in his own ability to cope with these aspects and in many cases creates confidence and group unity which makes it possible for things to be done which would otherwise be impossible. Magic, then, has the positive function of integrating group action, sustaining group morale and unity, and reassuring personal fears by offering some active and positive method of coping with what empirically is beyond the control and understanding of man. On the other hand, certain types of magic are negatively functional, i. e., dysfunctional in their disturbing, subversive impact on morale, unity, and group actions.

From Malinowski's analysis, we can conclude that magic has no genuinely objective, manifest functions, for its avowed empirical ends are related to the means used in a transcendental, non-observable manner. The only genuinely objective functions which Malinowski locates for magic are latent ones, fulfilling psychological and social needs of which the individuals are not conscious but the presence of which, along with the avowed subjective purpose and "imputed" manifest functions, explain the persistence of this cultural system.

In connection with this last statement, we should like to point out that Merton, in his treatment of manifest and latent function, overlooks the fact

that, while there may be no manifest functions as objective, verifiable consequences of one item for the maintenance needs of the other given items, the "imputed" or "spurious" manifest functions may be of great importance in explaining the persistence of some cultural items. In other words, Malinowski makes it clear that, though the Trobriand Islanders would accept an empirically established principle if it were available before they would use magical technique, the fact remains that they had a qualified belief and faith in the efficacy of magic. They thus not only used magic for a given purpose but had faith that, if used properly, the magical techniques objectively produced the intended results. In an *ex post facto* judgment, proper use was imputedly verified by the manifest appearance of the stated purpose of the technique. Erroneously imputed or else nonevaluable manifest functions may thus be a factor in explaining the persistence of a cultural item, as well as latent function and subjectively intended purpose. Sociologists and anthropologists well know by now that the reality which is effective in meaningful human action is that which is subjectively defined as real. If "imputed" manifest functions are thought to result from purposive actions, they are as real explanatory factors of action occurrence and pattern persistence as the objectively evident manifest and latent functions.

To illustrate this point further, let us look at the *kamkokola* ceremony. This was one of the three or four principal ceremonies of the Trobriand gardening cycle and came when the yam gardens of the Trobrianders were cleared. The *kamkokola* was a structure erected on the four corners of every yam garden plot. The most important of these structures stood at the magical corner of the garden: the special corner where many of the other ceremonies were performed and where the spirits were housed. *(4, p. 128)*

The *kamkokola* and the *kamkokola* ceremony are found to have several functions. First of all, the natives realized that the structure was of positive empirical value because the higher the taytu vines, the better they developed underground. This involved both an explicit purpose and a manifest function: an intended, verifiable, objective consequence. Secondly, there was the mystical feeling of the natives that somehow the height and strength and aesthetic quality of the poles had a stimulating effect on the young plants. This involved an explicit purpose but also an "imputed" or "spurious" manifest function: the native believed this relationship to hold and the purpose of the poles to have the intended consequence when the yield was good. It was, however, a nonempirical, nonverifiable imputation. Thirdly, the magical ceremony was the last decorative touch given to the magical corner before the vine supports were raised. It was thus inaugurative to the erection of the vine supports. Fourthly, it was of definite aesthetic value. The inaugurative and aesthetic functions of this ceremony were latent functions, perceived during lengthy field investigation by Malinowski into the whole gardening complex. *(4, p. 121ff)*

The *urigubu* gift from the brother to his sister's family consisted of a certain portion of his best yams from each crop. Here the manifest function, if there is any, is not isolated by Malinowski. It was not simply an economic transaction, but had the latent function of recognizing in a tangible fashion the moral duty of the male to the matrilineal line being perpetuated through the children of his sister. It was also a major element in marriage stability, a channel of levying tribute by chiefs, and expressed the real constitution of the Trobriand kinship grouping in which there was a compromise between the patrilocal household and matrilineal filiation. *(4, pp. 176ff)*

Malinowski sees religion growing up about the more vital events of life: birth, providence, death, adulthood, etc. The basic difference between magic and religion is that in religion the rites and ceremonies are not directed toward an empirical end but are ends in themselves. *(3, pp. 20ff)* In other words, being largely expressive in nature, there are no explicit purposes, no imputed manifest functions, and no genuine manifest functions in religious ceremonies connected with these vital events. There are, however, latent functions connected with each of these and explaining their persistence.

Had one the time, it would be possible to carry this analysis on into Malinowski's functional treatment of language, of the *bwayma* or central storehouse, the land tenure system, agricultural products, *kula*, law, myth, and many

other patterns and systems of the Trobrianders. In some of these, it is impossible to isolate any manifest function in Malinowski's ethnographic reports. This is to be expected both because he was not working explicitly in terms of this frame of reference and because articulated subjective purposes are not attached to all deeply ingrained normative patterns and systems, hence there is no possibility of checking the rationalized purpose against the objective consequences. This is true even, though to a lesser degree, in our own culture and other mobile cultures like it, where extensive rationalization is a prominent feature. The significance of Malinowski's functionalism is that it demonstrates that purpose and function are not the same, that it is possible to distinguish the objective consequences which are intended from those that are hidden and latent, that subjectively imputed or spurious manifest functions can be distinguished from genuinely objective manifest functions, and that the principal contribution that sociologists and anthropologists can make in the functional study of cultural items is hunting for the positive and negative unilateral and interdependent relationships of a latent variety existing between specified elements of social structure within specified ranges of influence.

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NEGRO-WHITE DIFFERENTIAL MARITAL FERTILITY

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There is a large body of data relating to racial differential fertility. In this paper the attempt is to bring together some of the more significant studies and findings and raise some questions and suggest some areas and problems of needed research.

One of the functional prerequisites for the survival of any cultural group or society is a positive net reproduction rate. In the American social system reproduction is expected to take place within the legal framework of marriage.

It is common knowledge that our rate of reproduction has been declining for the past one half century or more. This holds true for all racial and social groups. Part of the traditional stereotype is that the Negro reproduces at a higher rate than do native whites. The facts when subjected to rigorous analysis do not support the stereotype. The available data are limited and the conclusions cannot be accepted as absolute and final. Data on socio-economic groups within the Negro population are even more limited than data for the Negro and white populations. Most of the available data are confined to Northern urban areas. There are a number of good reasons for this, among them being the fact that vital statistics for this area are more complete and accurate. The data and conclusions, if they prove nothing else, show a need for more data in this field.

Differential fertility rates mean different rates of increase for different groups within a population. In dealing with differential birth rates we are dealing primarily with reproductive behavior as it is influenced by different social conditions. There is good authority supporting differential fertility by socioeconomic educational groups in the United States. It is recognized at the outset that the birth rate is not an ideal measure of conception. The measurement of actual differential fertility is further handicapped when fertility rates are restricted to women married only once and living with their husbands. This would eliminate mothers separated, divorced, and widowed and all mothers of illegitimate children. Another fact that must be recognized is that all births are not recorded in vital statistics reports. The limiting of reproductive rates to the reported births of women married only once and living with their husbands will give a reliable index of reproductive rates assuming that the number of births outside the framework of marriage is not sufficiently large to alter the rates and trends in now available data.

Certain social factors, which seem to be rather deterministic in the exercise of fecundity under current conditions in American culture have been selected for study. Among these are such factors as urbanization, social class, wealth, occupation of the family head, and education of the wife. In using these variables it must be recognized that each of them is a complex of social factors most of which are interrelated and all of which are associated with a variety of environmental and experience variables. Education is indicative of a complex of social circumstances: delay in marriage; increased standard of living, which tends to increase conflict between the individual's desire for children and his desire for economic goods; social status; individuation; and an awareness of numerous social pressures. Most of these circumstances operate against fertility.

The traditional belief and expectation is that Negro birth rates are higher than rates for whites. This expectation is supported if only crude birth rates are studied. Virtually the opposite is found if the comparison is put on the basis of more refined indices of fertility. In an analysis of the National Health Survey material, Kiser reports that

> The crude birth rates tended to be higher among colored than white wives, the opposite situation tended to prevail when the analysis was restricted to married women of child-bearing age.... In the combined data for all urban areas included in the Survey, the stand-

ardized rate in 1935 per 1000 women of child bearing age was 96 among native white wives and 86 among the colored.[1]

With moderate corrections for under-enumeration the rate for colored wives was lower than those for native white wives. Part of the explanation is the undue high proportion of childless marriages in the Negro group. Notestein,[2] in an analysis of 1930 census material for the East North Central States, reported the high incidence of childlessness among urban married Negroes. His data related to the average number of resident children under 10 years of age per marriage of 5-9 years duration, classified by nativity and color of head, by type of community and value of the home. In all types of communities, except rural farm, the fertility levels of Negro marriages fell below those for whites. When the comparisons were made on the basis of number of children under 10 per mother married 5-9 years, however, the Negro fertility indices were consistently higher in each type of community. This reversal was due to the large percentage of childlessness among urban Negro marriages. In the combined urban areas of the East North Central States, the proportion of childless marriages was 45 per cent among Negroes, 23 per cent among native whites, and 18 per cent among foreign-born whites.

It seems that there are certain biases in the Notestein study that should be taken into consideration. The study was based on the number of children born and under 10 in residence. This would eliminate all children who had died before the age of 10 or who were not living in household. Also the data related to unbroken marriages in which (1) neither the husband nor wife had been married more than once, (2) the wife was the home maker, (3) the husband was under 61 and the wife under 51 years of age, and (4) the wife had contracted her marriage between the ages of 15 and 40.

Kiser analyzing family surveys of whites in Columbus, Ohio, and Syracuse, New York, and Negroes in selected sections of the Harlem, New York City area found similar results. About 55 percent of the Harlem wives reported no children.[3] "A side analysis confined to 139 native Negro wives of all classes 40 years of age and over and indicated that approximately 44 per cent of such virtually complete families in Harlem were fruitless (confined to marriages which remained unbroken and were spent in Northern cities during the fertile years of married life). Comparable percentages for 228 wives of skilled workers in Columbus and for 305 in Syracuse were 18 and 22 respectively.

The high proportion of childlessness would lead one to believe that the Northern urban Negro wife practices contraception quite effectively. There are not too many available data on the practice of contraception and the effectiveness of such practices, but what there are do not seem to support such a point of view. Pearl reports, in a study on fertility and contraception in New York, and Chicago that "attempted contraception was less frequent and less effective among Negroes than among whites in the samples from both cities".[4] Pearl in a different study of urban areas found that about 35.8 per cent of the white women and 15.4 per cent of the Negro women in his sample had practiced some form of interference with conception.[5] Pearl's finding would indicate that about 64 per cent of the white wives and 84 per cent of the Negro wives did not practice contraception. The conditions under which the information was collected reduced the area of falsification to a minimum. Pearl's second study takes into consideration only those women delivering in hospitals during the period of the study, but the findings do tend to shed some light on the extent of contraceptive practices.

[1]Kiser, C. V., *Group Differences in Urban Fertility*, the William and Brown Co., Baltimore, P. 30.

[2]Notestein, F. W., *Differential Fertility in the East North Central States*, The Milbank Memorial Fund Quarterly, Vol. VI, No 2, Apr., 1938.

[3]Kiser, Clyde V., Birth Rates Among Rural Migrants in Cities, The Milbank Memorial Fund Quarterly, Vol. XVI, No 4, Oct., 1938, pp 369-81.

[4]Pearl, Raymond, *Fertility and Contraception in New York & Chicago*, The Journal of the American Medical Association, Apr. 24, 1937, Vol. 108, P 1389-90.

[5]*Preliminary Notes on a Cooperative Investigation of Family Limitation*, The Milbank Memorial Fund Quarterly, Vol XI, No 1, Jan. 1933.

Using the leads and hypothesis of Notestein and Pearl, Beebe made a study of differential fertility of coal miners in West Virginia. This study included 539 married women of reproductive ages, 30 per cent Negro, 70 per cent white. Each woman was offered contraceptive aid. Beebe reports:

> The inference seems justified that the Negroes as a group have an involuntary basis for their lower fertility....Among the Negro non-contraceptors the percentage reporting no live births is 31 and significantly above the percentage of 18 for whites. Rates based upon fertile women reduced the differential between 17 and 28 to one between 22 and 31, the latter also being well outside the change range. In other words, while Negroes exhibit a markedly higher childlessness this fact alone by no means accounts for the lower fertility in the present sample".[6]

The Beebe study seems to confirm previous data on the high proportion of childlessness in Negro marriages. He also reports that fertile Negro marriages are less fertile than the white. This seems to be a contradiction to the Notestein finding in his 1930 census data. All of the data still support the contention that the Negro has a lower marital fertility rate, but the hypothesis of more effective practice of contraception is not supported by the available data. One hypothesis sometimes stated is that the difficulties of adjustment inherent in the recent migration of Negroes to urban areas tend to reduce birth rates. Kiser, in an analysis of approximately 2,300 Negro families in selected areas of Harlem sections of New York City, reports findings that fail to support such a hypothesis. In his analysis Kiser says:

> The marital fertility within Northern cities was about the same for Negroes who migrated from Southern villages and rural areas as for Negroes of comparable age, social status who were born in the urban North. Birth rates were as low and the per cent of childlessness as high among Negroes born in Northern cities as among those born in Southern villages and rural areas".[7]

The available data support a differential marital fertility rates but the answer of why seems to be lacking. There is the possibility that present data are too few to be reliable and characteristic of the total population. For the moment let us assume that the data are correct. Why is this so? The two usually stated hypotheses are not supported by the data. First, the Negro couple does not practice contraception more effectively than any other group, and secondly, difficulties in adjustment to an urban environment do not account for the low rates. The Southern rural Negro does have a higher marital fertility rate than does the Negro in the North. Once in the urban environment his rates do not differ appreciably from the Negro born in the urban North. This seems to imply that he acquires very quickly birth rate patterns of the urban North. There are other possible explanations but at present there are no data to support them. One is that there is a high rate of involuntary childlessness in the Negro group, and that this is particularly characteristic of the Negro group.

Data on marital fertility rates in rural areas are less complete than in urban areas. Notestein[8] in his study of the East North Central States reported a higher marital fertility rate for rural Negroes than for urban whites but lower than rates for rural whites. Beebe[9] in his analysis of differential fertility rates of Miners in Logan County, West Virginia reported lower fertility rates for Negroes. Kiser's[10] compared marital fertility rates of whites and Negroes in purely rural areas of Georgia were about 9 per cent lower for colored wives. Kiser also reported that the rates for the rural Negro wives were lower than rates for Negro wives living in the Southern urban areas. This finding, I have a feeling, is due in part, if not wholly, to under-enumeration. This is at best only a guess. We need more data on different areas before we can say with

[6]Beebe, Gilbert W. *Differential Fertility by Color for Coal Miners* in Logan County, West Virginia, The Milbank Memorial Fund Quarterly, Vol XIX, No 2, April, 1941, p 189-195.

[7]Kiser, op. cit., p 369-381.

[8]Notestein, op. cit.

[9]Beebe, op. cit.

[10]Kiser, op. cit.

finality, although Kiser's analysis of the Family Survey material in selected areas of Harlem, at least, implies a lower birth rate for rural Southern-born wives than for wives born in urban areas.

T. Lynn Smith made a study of the population of Louisiana.[11] His findings tend to support previous findings of lower fertility rates of the Negro. Smith summarized his findings:

> 1. In the State as a whole Negroes seem to be multiplying slightly more rapidly than the white population, but this appears to be due to the fact that a higher proportion of the colored population resides amid rural surroundings.
>
> 2. In the cities the white population seems to be reproducing more rapidly than the Negro, while on the farm the opposite is true. In rural non-farm areas, the advantage also appears to be slightly in favor of the white population. However, in the Delta-cotton plantation sections along the Mississippi River, where such a large share of the State's Negroes are concentrated, the white population who live on farms are reproducing much more rapidly than the Negro.
>
> 3. On the whole, the white population of Anglo-saxon Protestant North Louisiana is multiplying more rapidly than the Negro, while in French Catholic South Louisiana, the advantage lies with the colored race.

The present body of available data tends to indicate a lower marital fertility rate for Negroes.

Data on differential fertility within the Negro group is less extensive and less conclusive than differential data relating to the Negro and white group. Our open class society makes it rather difficult to set up definite criteria of class. Three of the major avenues to higher social status are education, family income, and occupation of the head of the family. Data on marital fertility of socio-economic classes in the white group show an inverse relation between fertility and educational attainment of the wife. Kiser's analysis of the National Health Survey Material does not reflect the inverse relationship for the Negro group. Kiser reports:[12]

> "Among colored wives in the total sample the fertility for the minority reporting college attendance was relatively low. There was a marked similarity in fertility among the more important subdivisions of the sample along educational lines. This similarity held true at all ages. The analysis by area and size of city also confirmed the general lack of substantial variation in birth rates of urban colored wives."

A study of marital fertility of the Negro in Madison, Wisconsin, by education failed to show an inverse relation between education and fertility. In this study there was no significant difference in fertility rates on the scale from 1 to 12 years of schooling. Part of the explanation might be found in the relationship between marriage and opportunity for employment of the Negro woman of 12 years or less of schooling. Within the Negro group the occupational opportunities are limited for both the male and female. In the larger American society, the pattern seems to be the higher the educational level of the wife, the more likely she will have occupational and other activities that operate against having a large number of children.

One would expect an inverse relationship between fertility and occupation of the head of the family and education of the wife. The present data seem to indicate that such relationships do not hold for the Negro. The caste-like position of the Negro in American society tends to circumscribe his areas of social participation. In general, Negroes are expected to associate with Negroes only. This expected association has developed into what could be termed Negro society. The pattern of behavior and values of the Negro within his own group tend to follow the pattern and values of the larger American Society, but with some modifications.

[11]Smith, T. Lynn, *Population Analysis*, McGraw-Hill, 1948, p. 216.

[12]Kiser, Clyde V., *Group Differences in Urban Fertility*, The Wms. and Wilkins Co., Baltimore, 1942, p. 110.

In Warren S. Thompson's study of "Differentials in Fertility and Levels of Living in Rural United States," his findings support the hypothesis of an inverse relationship between levels of living and fertility for both whites and nonwhites. On racial differences in fertility, Thompson says "what many people have thought of as racial differences in fertility turn out to be more closely associated with level of living than race. When white and non-white belong to the same level of living group, they have much the same fertility such difference as there is being largely in favor of the whites."[13]

The present body of data indicates a lower marital fertility rate for Negroes than for whites although the Negro has the higher crude fertility rate. The higher proportion of childlessness seems to indicate that Negro wives tend to practice contraception more effectively than white wives, yet the data do not support such an assumption. On the other hand, Negro mothers have a higher incidence of fertility than white mothers. This raises these questions: Is the high proportion of childlessness among Negroes involuntary? If it is involuntary, are the factors that contribute to sterility peculiarly characteristic of the Negro? If it is voluntary, why do such a large percentage of the Negro couples choose to remain childless?

If Thompson is correct in stating that fertility is more closely associated with levels of living than race, our question is, where on the level of living scale does the level of living begin to operate against fertility? What, if any are the differentials in the level of living at which they begin to operate against fertility in the white and Negro groups? Such an approach to differential fertility, by its very nature, means investigating one of the most private and personal areas of family living. But if it ever becomes necessary for us to formulate a population policy, we shall need accurate knowledge in this area.

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[13]Thompson, Warren S., *Differentials in Fertility and Levels of Living in Rural Population of the U. S.*, American Sociological Review, Vol. 13, No 5, Oct. 1948, P. 516-34.

AN AREA COURSE IN ACTION

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(A report of an area course in the natural sciences as developed and taught at The College of the Ozarks, Clarksville, Arkansas)

"Modern College Education: Does It Educate in the Broadest and Most Liberal Sense of the Term?" The writer of the article bearing this title continued by saying that, "However much a class of professors, safe from the world's clamor within their own cloisters, may imagine that the education which young men receive is satisfactory and the best that can be given them, they must eventually come to recognize that there is a large and growing class of men who think that a great portion of our university education is absolutely wasteful... ...courses that are essential to a man's proper development, subsequent sucess (success being meant in its best sense) and usefullness to himself and his fellowman are either entirely omitted or so imperfectly treated as to be of little value.... "[1] The author? John Brisbane Walker, editor, *The Cosmopolitan* February, 1950? ---no--- 1900.

Yet this author fifty years ago asked the same questions we as teachers and educators are asking ourselves today. We feel that with so many specialized areas requiring specific skills and techniques, our college and university curricula frequently leave our graduates totally unprepared to meet the confusions, complexities and pressures of our family, community, national and international environment. In an effort to overcome this lack in the education of our youth, new courses, new combinations of courses, study of great books, discussions of great issues, core curricula--all have been proposed as possible solutions. As yet no answer has been found, nor probably will be found soon, but we continue to seek and to experiment.

Many educators have advocated the area course, a course dealing with the broad basic principles in an entire field such as the natural sciences, as a means of giving the student a better understanding of the different phases of his environment.

This is a report of an area course in the natural sciences as developed at The College of the Ozarks. Two years ago we discussed before this academy the place of area courses in the field of natural sciences. As a follow-up study, we gave out a questionnaire here and at the science division of *The Conference on Higher Education* (1949 meetings). Fifteen replies were received representing nine Arkansas colleges and two out-of-state colleges. (In some cases replies were received from more than one instructor in the same college)

The replies showed that a number of the science instructors in Arkansas are interested in a non-technical science course which emphasizes broad basic principles of both the physical and biological sciences. There was a good deal of agreement as to content, nature of the course, and time allotted to physical and biological material and as to the method of presentation.

The topics which a majority felt should be included can be summarized under about eight major subjects--*matter*, its structure, properties, changes; *energy*, sources, kinds, transformations, electricity, heat, light; *geological ages and earth history*, formation of soils, weather and climate; *evolution*; *solar system*, structure and origin; *food and food production*; *physiology of the body systems*; *health and disease control*. One very practical suggestion was that the course should include a study of *local flora and fauna*.

[1]*The Cosmopolitan*: John Brisbane Walker, editor, February, 1900, Volume XXVIII No. 4.

A separate course in the biological and physical sciences was preferred 10 to 5, although the combined course was considered ideal. The method of teaching preferred was the lecture-demonstration-laboratory plan (9 of 15). Most agreed that less time should be spent on lab.--more demonstrations (10 of 15). One teacher in charge was considered most effective (8 of 15). Nearly all allotted equal amounts of time to the biological and physical material.

This information was helpful in developing our area course at The College of the Ozarks. The faculty voted to offer such a course and after the division of natural sciences discussed objectives and general plans, we were asked to develop and teach the course. The experiment began with the spring quarter of 1950.

The course was to be a two-quarter course combining both biological and physical sciences. (If this were the ideal plan, then why not try it.) We set up these specific objectives for the course.

1. To give the student certain concepts and principles of science that will help him see the many interrelationships of scientific development and everyday living.
2. To instill in the student the idea of approaching every problem with an open mind, collecting all possible data on the problem, and giving the data critical appraisal before reaching a decision.
3. To help the student have an understanding of the history and development of science.
4. To give the student an understanding of the value of fundamental and applied research, the need and use of both in our day by day living.
5. To have the student feel the sense of orderliness in the universe, in our planet, and even in our own lives from the microscopic to the astronomical.
6. To develop in the student through the study of the precise laws and relationships of our natural world, a number sense and an appreciation of quantitative values.
7. To enable the student to become familiar enough with the general terminology of science and to have a background for reading intelligently and critically books and articles on scientific matters.
8. To have the student become aware of the fact that scientific developments have produced definite and profound changes in our social and economic life; that such advances as the control of diseases, improvement in medical and health practices have brought new problems in population distribution, in the feeding and care of the world; that these new problems must be solved; and that, with the solving, other problems will develop which will have to be solved--that there always will be a challenge to the thinking person.

Most of all, we wanted our students to see that science is ever seeking the truth and that each new discovery brings changes in the total picture, discards old theories, revises others, opens new vistas and brings us a bit closer to ultimate truth and understanding. Such were our aims in planning the course.

These aims were more of a challenge than they might seem when put alongside the student's reasons for taking the course. The first two classes (38 students) were asked to list the reasons why they were taking the course. Twenty-three listed first *"Required"* (The course itself was not actually required but could be taken instead of the usual science requirement.) Three listed *"Required"* second; two listed it third. It was somewhere on each list. A few mentioned an interest in science and some in-service teachers thought it would help them in teaching *One took it because it fitted into his schedule.* So with ego properly deflated we launched our area course.

The course was built around four major questions. First, "Where did we come from?" This dealt with matter and energy as beginning materials, the relationship of one to the other, basic laws, nature and forms. Following the study of the basic entities we took up origins--origins of the universe, solar system, earth and finally life.

After that was "How has life changed and developed?" The geological ages, changes, physical and biological, in our universe were presented. Environment and our relationship to it and it to us was studied emphasizing both the physical and biological factors.

The third question--"What of today?" had to do with the problems of maintenance of life, our basic needs for survival, natural resources and their conservation, sources and utilization of power, health and disease control, heredity in race and nationality problems. The role of scientific research in solving these problems, chances of survival, problems yet to be solved--were all considered.

The last question--"What next?" was a sort of look into the future. The place of eugenics in our development, the possible uses of nuclear energy, applied versus pure research, the need, value and purpose of each, the possible direct utilization of the sun's power, cosmic rays and their place in the energy picture--even space explorations were discussed. Of course, no definite answers could be supplied, but we did attempt to make the student conscious of these factors in our life, the possible developments and the need for serious and concerned thought about these possibilities and their effect on our present social order.

Dr. Beach, the present instructor, has been following about the same general plan. His major units are (1) Raw Materials, (2) The Structure of the Universe, (3) The Physical and Biological Factors of Environment and the Interrelationship of the Environment with the Individual and (4) Problems of Maintenance and Survival. Our detailed outlines of these units paralleled each other very closely in the actual material covered.

Evidence that these major questions were of special interest to the students was shown in the topics listed by them at the beginning of the course as topics they would like discussed.

The topics listed most often were:

1. The relationship of man to his environment, getting acquainted with our natural world, sources and production, control of human machine, and why air is useful to man.
2. The origin and development of life, the universe, the solar system, and names of planets and constellations.
3. Conservation of our natural resources.
4. Control and prevention of disease.
5. Meteorology and weather conditions.

Several said they would be interested in any topics which might be studied--since "I don't know anything at all about science." Notice the agreement of choice in topics to be studied as listed by instructors and by students. It gives us reason to believe that these major issues should be the basis of any general course in the natural sciences.

Dr. Beach and I also followed somewhat similar methods of presentation of material. We used the lecture-domonstration-laboratory combination preferred by most of the instructors of the state answering our questionnaire. There were no assigned laboratory periods. Demonstrations as well as individual experiments were performed during the class period. Occasional field trips were made. Also the students had certain projects they had to bring to class. A collection of different minerals found nearby, and of local animals and plants was required. These collections were small but helped the student to become aware of the complex living and non-living environment of which he is a part. A film on the motions of the solar system was used. (Others are available and should be used.) Oral reports for which extra points could be earned were quite popular. Class discussions were a favorite with most students and showed serious interest in the major issues of science. Frequent panel discussions assured everyone a chance to have his "say". Material for their discussions came from reading references in periodicals, newspapers, current magazines and books. In fact, no one textbook was used--only references.

Testing and evaluation has always been a problem. Since in this course there was both factual and debatable material, we used the objective and the essay type questions for examinations. Quizzes were given rather frequently.

Dr. Beach gave weekly quizzes using about half of the period for each test. We gave tests at the end of each of the smaller units into which the major ones were subdivided. These came every two or three weeks. There was a final test over the entire course. This was counted as approximately one-fourth of the student's final grade.

Some sample questions from both Dr. Beach's and my tests are:

1. Name the form of energy described: waves transmitted by water____ _____, molecules of gas in motion (not kinetic)_____, electrons traveling through metal_____.
2. The third planet from the sun is_____.
3. What possible sources of energy may be developed in the future?
4. Can scientific methods and principles be applied to social and moral areas? Explain your answer.
5. Name factors that (a) favor and (b) hinder the spread of living species over the earth.
6. Does a highly specialized or a generalized type of organism have the most chance of survival? Explain.
7. What activities remove oxygen from the air, and what other activities return oxygen to the air?
8. List four problems facing the survival of man and suggest possible solutions science may be able to offer.
9. Discuss one of the theories of the origin of the solar system. Give evidence to support and to refute the theory.

Of course, many of these discussion questions have no specific answer. If they did all our problems would be solved. But evidence was weighed pro and con, possibilities suggested and discussed. The part scientific research and development might play in the solutions, the resources available, developed and undeveloped, were mentioned with the hope that the student might become more aware of vital problems facing him, the methods being used to find a solution and some of the possible solutions. For example, soil improvement and conservation, hydroponics, more nutritious foods, synthetic foods were some of the factors discussed as having a part in the food problem. In these discussions we hoped not only to make the student conscious of the problem but to give him sufficient factual background on the problem to enable him to weigh evidence and make judgments on an understanding basis.

The proof of the pudding is in the eating--and the real test of the course is "What did the students think of it?" and "What did they get out of it?" Seeking an honest evaluation of what the students really thought of the course, we gave a questionnaire at the end of each term. The students were told to be perfectly frank and that the answers would have no effect on the grades--in fact would not be read and tabulated until after the grades were in. Most of the answers seemed to indicate that the students tried to make honest evaluations.

Of the eighty-one taking the course, sixty-two turned in replies to the questionnaire. We will let the replies speak for themselves.

1. Has your interest in scientific development and research been stimulated by this course?
   (59) Yes
   (3) No
2. If so, in what way?
   (43) Realize the impact of science in our daily life is greater than I ever thought.
   (28) Understand and appreciate more the development of our modern conveniences.
   (16) Read more articles and books of a scientific nature.
   (14) Are interested in studying national issues controlling scientific research.
   (13) Desire to study more in detail some particular field of science. (This was interesting and encouraging.)

3. Has this study helped you to understand scientific data and articles about scientific work?
   (60) Yes
   (1) No

4. If so, in what way?
   (53) Find such articles more interesting now since I have studied in class some of the topics discussed.
   (22) Have learned the meaning of certain scientific terms commonly used in scientific literature.
   (10) Know the meaning of formulas commonly listed in scientific articles.

5. List the topics about which you learned something new.
   (19) The origin and development of life--geological ages, cell theory, etc.
   (19) The structure and organization of the solar system, planets, planetary motions, origin, earth history.
   (16) Reproduction, sexual and asexual.
   (13) Atomic energy, use and development.
   (13) Energy, laws, transformations, kinds, sources, possible development.

6. Method of presentation preferred.
   (22) Wanted more laboratory work and student projects (Compare this reply with the reply from the instructors in which less laboratory was favored.)
   (21) Wanted more student discussions. (Evidently our students like to be a part of the class--not just to be talked at.)
   (10) More specific study questions to answer.
   (9) More lectures.
   (4) More outside lecturers.
   (7) More student reports and papers. (Again the student wants to *do* something in class.)

7. How would you prefer to spend your time in the course?
   (9) Physical Science alone.
   (4) Biological Science alone.
   (13) Separate course for Biological and Physical Sciences.
   (2) Some specific science.
   (34) Gave no answer or stated specifically they liked the course as it was.

8. Should we spend more time on certain topics and go into them more in detail?
   (25) Yes
   (29) No
   (8) No answer

9. List topics about which more should be discussed. The subjects suggested most frequently were:

   Origin of life, universe, solar system, geological ages.
   Research in medical and health problems.
   Food problems.
   Nuclear energy and genetics.

10. Should we spend less time on certain topics and study more topics.
    (9) Yes
    (50) No
    (3) No answer

11. List topics on which too much time was spent.
    None listed.

12. List topics which were not discussed or were not discussed enough but which you feel should be emphasized. The topics listed were:
    Conservation of our natural resources.
    The development of man.
    Disproving superstitions.

13. What suggestions do you have for improving the course?
    (19) A regular textbook.
    (13) More copies of the reference books.
    (13) More detailed outlines.
    (11) More current articles.
    One very helpful suggestion, one we plan to adopt, was to have a *scientific word list*, listing terms which would be used throughout the course. Again, more lab. was suggested.

14. What criticisms do you have of the course?
    (45) No criticism.
    (12) Over my head most of the time.
    (4) Too general.
    (1) More lab. and student projects.
    One student very emphatically stated he didn't see why the instructor's viewpoint was the only correct one. (Neither do we--but that's what he said.)

15. What should the length of the course be?
    (35) Two quarters.
    (13) Three quarters.
    (9) One quarter enough.
    (5) No answer.

16. Would you have taken the course had you known at the beginning more of the nature of the course?
    (53) Yes
    (3) No
    (6) No answer

17. Do you prefer this plan of meeting the science requirement for graduation?
    (49) Yes
    (5) Prefer present plan of 10 hours of specific courses in biology, physical sciences or mathematics.
    (8) No answer.

Summarizing the results of the questionnaire, we might say these conclusions express the opinion of the majority of the students.

1. There was an increased interest in science and a better understanding of its impact on our daily life. Thirteen felt they wanted to continue their study, taking up some particular field of science.
2. The students found science articles on topics about which they had studied in class more interesting.
3. They definitely wanted more student participation in the course, more laboratory work, more reports and student projects, more student discussions.
4. In general the combined course was preferred. Although a few (13) would like separate general courses in the two fields, only 2 preferred the traditional specific beginning courses such as Botany 101 or Chemistry 101.
5. Only 9 wanted more topics with less time on each. No topic was listed as one on which too much time was spent.
6. A goodly number (19) wanted a textbook, but most of them wanted either more copies of the references, more references or more current articles.
7. Most of the students had no criticism of the course. Four thought it too general and 12 felt it was over their heads most of the time.
8. Two quarters was thought to be sufficient for such a course.
9. Most of the students liked the course and preferred it to the present science requirement for graduation. Only 5 of the 81 thought the present plan of 10 hours in a specific science or in mathematics better. Only 3 of the students would not have taken the course had they known in the beginning more about the nature of the course.

Some of the comments about the course were revealing in themselves and are quoted here for whatever consideration and evaluation they merit.

"If the second quarter will be as interesting as the first, I wouldn't miss it for all the tea in China."

"This course should help a student decide what particular field of science he would like to follow."

"My education would have been incomplete without this course. If I had known what I was missing I would have minored in science." A senior physical education major.

"I never cared for science until now--my curiosity has been aroused, and I am going to pursue more knowledge of it."

"The instructor has set the mold and we as students were expected to come out perfect finished products.....why be so specific on examples of scientific principles unknown in the natural environment of a majority of the class?" The same sophomore in education who felt the only acceptable viewpoints were the instructor's.

"Feel my time in this class well spent. I appreciate your attitude in every way."

"I have had questions answered about which I have wondered but didn't know how to go about getting the answers for myself."

"I have learned many things in this course that will help me in my school work." This was an in-service teacher.

"Stimulates thought and brings an appreciation of the things we have now."

"The course offered just what I wanted and needed. I do not desire to study and particular field of science but to be able to observe natural science day by day and to know something about scientific terms as used in newspapers and magazines as connected with current events."

What then, if anything, can we conclude about the course? Is it worthwhile? Does it have a place in the natural sciences? Does such a course have a place in the college program of our youth? Did we achieve our objectives?

We can draw no absolute conclusions. From the comments of the students and from their responses on the questionnaire, we feel a definite interest in science was developed and that this interest was reflected in increased reading of scientific articles in current magazines, periodicals and newspapers. Evidence of this was further shown by the fact that the students brought to or told the instructor of interesting articles on science--even after finishing the class. We also feel that those who took the course are more aware of the role science plays in their social, political and economic life and of the role research, fundamental and applied, has had in our development.

We accomplished little in developing a number sense in the students. A specific mathematics course of basic principles will probably have to be given to develop particularly a quantitative sense.

Nor can we claim that each of our students henceforth will examine every issue he faces critically with an open mind. In fact, we are sure most will not. Age-old prejudices continually cropped up and persisted regardless of actual facts presented. The "I don't care if it is so, I won't believe it" attitude was not erased. Neither was the, "This is the way it is" attitude lost. Background--miner, teacher, farmer, politician, high or low income--all played their part in the interpretation and acceptance of the material presented. (Doesn't it for all of us?)

But we do believe that at least a few new ideas slipped in. A fair majority looked honestly and critically at some of our major problems in which science plays a great part--and were challenged.

The course seems to be meeting a real need for the non-science major at The College of the Ozarks. And since it seems to meet a real need we feel it has its place in the division of natural sciences. The fact that the enrollment in the course has increased and remained around twenty-five would seem to indicate continued interest.

As to its worthwhileness--only the students themselves will eventually answer that. Its ultimate worthwhileness can only be determined as those who have shared in its development as guinea pigs take their place in our complex society.

At least the teaching of the course has been a stimulating and interesting experiment to Dr. Beach and the author--one worth continuing--with certain revisions.